The results of a survey for rare Botrychium species (moonworts and grape-ferns)

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in the Wallowa-Whitman National Forest

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INTRODUCTION

In 1991, the Wallowa-Whitman National Forest and the Mt. Hood National Forest conducted a challenge cost share inventory with the Oregon Natural Heritage Program for rare Botrychium ferns. In the Wallowa-Whitman forest this work was concentrated in the Eagle Cap Ranger District, in the Wallowa Mountains of northeastern Oregon.

The major findings of this inventory are as follows:

1) The Wallowa Mountains are one of the most important centers of Botrychium diversity in the world. Fourteen species are found growing in this small geographic area. This represents 25% of the 55 reported species world-wide according to Warren Wagner (1990), who calls the Wallowas a "Botrychium Haven" (Wagner and Wagner 1986).

2) An new addition to the fern flora of Oregon was found (Botrychium paradoxum, paradox moonwort).

3) Two new moonwort species as yet undescribed in the fern literature were located. These species, new to science, are referred to in this report as "Species A" and "Species B".

4) Four species in the Wallowas are C2 federal candidates for listing under the Federal Endangered Species Act (B. ascendens, B. crenulatum, B. paradoxum and B. pedunculosum). Each is rare and is threatened in the Wallowas.

5) Eleven rare species of Botrychium are now known from the Wallowa-Whitman National Forest: B. ascendens, B. crenulatum, B. lanceolatum, B. lunaria, B. minganense, B. montanum, B. paradoxum, B. pedunculosum, B. pinnatum, B. species "A", and B. species "B".

6) The calcareous drainages of Hurricane Creek (in the wilderness) and the Lostine River (out of the wilderness) are the most important known concentrations of moonworts on the Eagle Cap Ranger District.

7) Most populations are small, with fewer than 25 individuals. Most populations are found on alluvial fans, floodplains, or other geologically recent deposits, in sunny mesic situations. These naturally disturbed sites probably represent the pre-settlement habitat for the species which are sometimes found on roadsides and trailsides.

8) Conflicting land uses threaten many moonwort populations. Threats include camping, compaction, erosion, pack animal trampling and grazing, domestic sheep grazing, exotic weeds, firewood cutting, increasing recreational use and the lack of effective recreation management planning.

9) Large and diverse Botrychium populations, which often occur with other rare vascular plants, deserve some special protection designations (Research Natural Areas, Outstanding Natural Areas, Botanical Special Interest Areas, Restricted Use Areas, No Camping

Zones, or No Grazing Zones). Wilderness designation is not adequate protection for rare plants.

10) Locating Botrychium is time-consuming and difficult. More surveys are needed to understand the status and distribution of moonworts in the Eagle Cap Ranger District. The discovery of two unnamed species in 1991 illustrates this need.

11) All management activities should be preceded by a mid-summer botanical survey, to determine if federal endangered species candidates are present and would be affected by the activities. Many of the high-use recreation areas in the Eagle Cap Wilderness should also receive a botanical survey to determine if sensitive plants occur in these areas. Botrychium species favor many of the open habitats used by recreational visitors and their pack animals.

12) The federal status as a C2 candidate should be reassessed and perhaps changed to C1 for Botrychium pedunculosum.

Part 1. Identification of Botrychium species.

Merely finding moonworts and grapeferns in the genus Botrychium is difficult. The plants are small, cryptically colored and grow among similarly-sized and -colored grasses and herbs (e.g., Wagner and Wagner 1981, 1990b). Table 1 gives a list of some of the troublesome "Botrychium mimics" commonly encountered in the field.

Inventory for moonworts requires locating appropriate habitats on a gross scale, and when in the correct habitat, intensively searching, often on hands and knees, for very small plants. Adequate searching may take hours or days depending on the size of the habitat and the density of the vegetation. While the plants are commonly found in aggregates (Wagner and Wagner 1983a), these aggregates are often absent from what appears to be acceptable habitat.

The size, vigor and abundance of the plants varies year by year depending on rainfall (Wagner and Wagner 1983b, Wagner and Devine 1989), predation and as yet undiscovered factors (Montgomery 1990).

The vexing subtlety of identification of Botrychium species has been remarked on by a number of authors (e.g., Cody and Britton 1989). The organisms have a simple morphology, which makes it easy to recognize the genus but difficult to name the species. Juvenile plants are invariably fertile, but tend to resemble one or more other species for several years. Even among well-developed mature plants the leaf outlines of different species are only slightly different. Fresh plants will yield some useful habitat and color clues. Pteridologists have found some chromosome and chemical differences between the species (Farrar and Johnson-Groh 1991) but most of these not available to the field botanist, and little of this information has been published (W. H. Wagner, pers. comm., Wagner and Wagner 1990a acknowledgments).

The subgenus Botrychium, moonworts, is the most diverse group in the Wallowa Mountains. Its taxonomy is controversial and constantly changing. New species continue to be described, but they are not accepted by all botanists. For example, "splitting" species (e.g. Wagner and Wagner 1981, 1982, 1983c, 1986, 1990b) yields eleven taxa in subgenus Botrychium in the northeastern United States. Cronquist's recent (1991) treatment of the subgenus in the same geographic area accepts only four full species, "lumping" the other taxa as weak varieties, phases, forms and chromosome races. Nonetheless, most biologists agree that evolution has resulted in a diversity of grapeferns and moonworts; what is disputed is the taxonomic rank to assign these variants. Even the widespread taxa Botrychium lunaria and B. minganense continue to generate diverging views, more than 60 years after Victorin (1927) split the latter from the former (Clausen 1938, Fernald 1950, Morton 1952, Wagner and Lord 1956, Hitchcock and Cronquist 1973, Cronquist et al. 1986, Wagner and Wagner 1990a, Cronquist 1991). For these species, taxonomy is a matter of opinion. During this survey the recent published work of W. H. Wagner and F. S. Wagner was found to be satisfactory when supplemented with in situ experience.

Field study of moonworts is necessary to develop identification skills. But substantial assistance is rendered from carefully pressed specimens (see D. Wagner 1991). Unfortunately there are few specimens in most herbaria, and many of the critical species are represented by empty folders or poorly prepared, wrinkled or folded plants (F. Wagner 1988, Wagner and Wagner 1990b). When specimens are completely flattened, showing their entire silhouette, they are most easily recognized. Color photographs of the plants in nature rarely have the requisite depth of field to be of much aid in identification. Line drawings of most of the new species do not exist in the scientific literature (see D. Wagner 1990). Hence illustrations in this report (Figures 1-15, Appendix 3) use photocopies of pressed collections. Careful study of the outlines is usually sufficient to provide an identification, if a number of leaves have been sampled. One or two leaves is not a sufficient sample for the small species. Intrinsic variability in the size and cutting of the leaves requires a larger sampling.

Sampling is constrained by the small size of populations. Nonetheless, the small species are usually misidentified, and collecting plants (above ground level, Wagner and Devine 1989) is usually the only way to be certain of the identity. Despite the contentions of aggressive collectors, there are no published data suggesting that the deciduous species are not harmed by removing leaves during the growing season. Collecting a minimum of 5-10 vouchers is usually necessary for identification of the smallest species. Mark large colonies, note color and three-dimensional aspects, and plan to return. Gathering specimens for study should be done late in the season, after the release of spores and as the leaf is starting to yellow or wither. Collect only the above-ground portion and do not disturb the roots. This procedure should allow the plant to survive and obtain maximum storage of photosynthate while yielding a useful taxonomic specimen.

Montgomery (1990) showed a large evergreen species survived repeated defoliation by predators. However, our only evergreen species, Botrychium multifidum, is common, well-documented in the herbaria, and is readily recognized at any time of the year. It is the grapefern in our flora that least needs to be collected to verify its identification! Well-documented peer-reviewed reports are needed to determine the impacts of leaf-removal (by botanists or grazing animals) during the growing season for the deciduous species. David Wagner initiated a study of this with B. simplex in 1991.

Livestock may have an adverse impact on some Botrychium. Farrar and Johnson-Groh (1991) reported several species in ungrazed prairie and their absence in adjacent grazed habitat in Minnesota. Wagner and Wagner (1983) noted that B. lanceolatum, B. pinnatum (and other species) are selectively browsed by native rabbits or large rodents. Unlike deer and livestock, these browsers nip off the sporophores, leave the leaf blades intact, and may disperse the spores in their droppings. The commonly seen clusters of plants may be established in this way. Animal dispersal of spore-producing plants is highly unusual, and it would be interesting to study this phenomenon.

Montgomery (1990) showed that the large evergreen species B. dissectum in Pennsylvania could survive more than five consecutive years of defoliation by white-tailed deer, presumably by relying on nutrients from a subterranean endophytic fungi. It has not been demonstrated that the deciduous species can withstand repeated defoliation by grazers.

Cultivation of sporophytes is not possible at the present time (Wagner and Wagner 1990b). A number of biologists are investigating raising the species from gametophytes, but this is a difficult technical process (Wagner et al. 1985, Whittier 1991), and can not be considered a management option.

Using the Identification Key in Appendix 2

There is no adequate existing key to the diversity of grapeferns in the survey area. Published keys for the Pacific Northwest (i.e., Abrams 1940, Peck 1961, Hitchcock and Cronquist 1973, Mason 1980, Lellinger 1985, Alverson 1985, Wagner and Devine 1989, Lorain 1990, W. Wagner and F. Wagner 1990a, D. Wagner 1991) are unable to keep pace with new species descriptions and new inventory results. The key provided in Appendix 2 is the work of D. Wagner (1991). I merely inserted leads for the three new Oregon taxa discovered during this survey. Within a year it too will be outdated.

The user is cautioned to read both leads in the keys before choosing a couplet to follow. Not all plants will key easily. Immature plants invariably bear sporangia (except B. virginiana), but are often insufficiently developed to allow identification using a key. These plants must be studied in nature, and compared with the color, aspect, stature, habitat, etc. of mature (larger) individuals in the population to make a tentative identification. Botanists generally do not expect to identify juvenile sedges or composites. They should not expect to be able to identify juvenile Botrychium plants. Hybrids are rare but present, and can be troublesome to name (Wagner and Wagner 1988, Wagner et al. 1984, 1985, W. Wagner 1991). Greater difficulty during identification arises from the intrinsic variability among individuals within any one species in the genus (Graham and Wagner 1991). W. Wagner (1990) discusses the differences between the subgenera of Botrychium, as they are currently defined.

Experience with the species in the field is essential, as is reference to good silhouette illustrations for comparison. D. Wagner is preparing a set of illustrations of the Oregon species (see also D. Wagner 1990, 1991); in the interim the illustrations of Appendix 3 are offered.

Part 2. Rare or overlooked?

Are the species rare? As in any large genus, some are and some are not. For example, Virginia grape-fern, or rattlesnake fern, Botrychium virginianum is so common it could be considered characteristic of fertile woodlands across the entire eastern deciduous forest in the U.S.. It also ranges the width of North America and extends into South America (W. Wagner 1990). In Oregon rattlesnake fern is locally common on the slopes of Mt. Hood, and is widely scattered elsewhere in the state. A sharp contrast is provided by the rarity of Botrychium pedunculosum, which grows nowhere else in the United States but in the Lostine River Valley. Botrychium habitat is generally common in the mountains of western North America, but many of the species are rare (Wagner and Devine 1989, Wagner and Wagner 1990b).

Table 2 provides a summary of the current status of each of Oregon's Botrychium species. While it is certain that populations have been overlooked in the past, and that more inventory is needed, none-the-less patterns of rarity and threats are emerging out of the existing data.

Botrychium lanceolatum, B. lunaria, B. minganense, B. multifidum, B. pinnatum, B. simplex, and B. virginianum are widespread and common to abundant in other parts of North America or the world. Of these taxa, B. multifidum, B. simplex and B. virginianum are occasional in Oregon and do not need special management attention on public land. Botrychium simplex and Botrychium virginianum are common enough that they should be removed from the Oregon Natural Heritage Program (ONHP) list 4 (taxa of concern currently not threatened or endangered) and dropped. The others (Botrychium lanceolatum, B. lunaria, B. minganense, B. pinnatum) should stay where they are, on List 2 (ONHP 1991): taxa threatened or endangered in Oregon but more common or stable elsewhere.

Botrychium montanum, endemic to western North America, remains rare in Oregon and should also stay on list 2.

Globally rare species in Oregon are Botrychium ascendens, B. crenulatum, B. paradoxum, and B. pedunculosum. Each is a C2 candidate for listing as a federal endangered species. The meager populations in Oregon, all of which are threatened by humans, supports C2 status and Oregon Dept. of Agriculture (ODA) candidate status under the Oregon Endangered Species Act. Each already has ODA candidate status, except for the recently discovered Botrychium paradoxum. ONHP rankings for all four species should be List 1: threatened or endangered throughout their range.

All Botrychium species currently on the U.S. Forest Service Region 6 sensitive plant list for Oregon should remain there. Botrychium paradoxum should be added the F.S. sensitive plant list for Oregon.

Three taxa in Oregon were left out of the above discussion. Botrychium pumicola, endemic to the Cascades of southern Oregon and northern California, is a C2 candidate for listing under the Federal Endangered Species Act. It is not found in the inventory area, and is not discussed further.

Two recently discovered, unnamed taxa (Species "A" and Species "B") in the Wallowas are rare, local, and threatened by human uses of their habitat. Species "A", at present, can be considered endemic to the Lostine River valley. Species "B" has been collected at 2 sites in the Wallowas, as well as in Colorado and the Gaspe (W. Wagner, Alverson, Houk, pers. comm.). More inventory is needed for both of the undescribed species to accurately determine their distribution and abundance in the Wallowas and elsewhere. At present, both undescribed species would qualify for review as C2 candidates for the federal endangered species list, based on their known distribution and threats.

Part 3. Survey results.

A more complete discussion of the status of each species in the Wallowa-Whitman National Forest is provided here. The data in Table 3 show known sites for taxa in the Eagle Cap Ranger District. Baker District provided a number of sighting records after the majority of this report was written. Those reports with adequate documentation (so that the species identifications could be verified) were included in the suggested status changes in Table 2 and in the range maps (Figures 1-15) in Appendix 2. The Washington Natural Heritage Program and the Colville National Forest also provided the results of recent survey work in their state, which was incorporated in the following sections.

Botrychium ascendens W. Wagner

Common name: Upward-lobed moonwort

Illustrations: Figure 1, Wagner and Wagner (1983b, 1986), Lellinger (1985), Wagner and Devine (1989), Lorain (1990), D. Wagner (1990, 1991)

Recognition: Appendix 2, Wagner and Wagner (1983b, 1986, 1990a), Wagner and Devine (1989), Lorain (1990), D. Wagner (1991)

Identification of Botrychium ascendens requires a period of acclimatization to the subtleties of the genus. It is closest to B. minganense and B. crenulatum, but depauperate specimens of B. simplex are often mistaken for it. The key (Appendix 2) provides distinctions between the species. Living plants are green, not gray-green, and have erect blades. The upper segments are strongly ascending, serving to distinguish it from B. crenulatum and B. minganense.

Hybrids: A single hybrid plant of B. ascendens X crenulatum was found at the type locality for B. ascendens (Wagner and Wagner 1986).

Distribution: Figure 1, Table 3

Figure 1 shows that upward-lobed moonwort is restricted to Wallowa County in Oregon. Beyond our state it is known from Montana, Nevada, California (Wagner and Devine 1989) and from the Canadian provinces of Alberta, British Columbia, Ontario and Yukon Territory (Wagner and Wagner 1986). Apparently most populations are small, with the exception of the type locality (Wagner and Wagner 1986). The numerous reports of this species from Washington State in 1991 are perhaps misidentified, as those sites are reputedly in cedar swamps. This would be highly atypical for the species, which in the Wallowas and in California is found only in mesic meadows. If the identifications are correct, the Washington plants are all threatened by proposed timber sales.

Wagner and Wagner (1986) did not record any other Oregon sites for Botrychium ascendens besides the type locality. Small populations of the species were found at three other locations on Hurricane Creek in 1991. These are shown in Figures 17b, 17c and 18.

Wagner and Wagner (1986) reported "hundreds" of plants from their visit in August 1983 to the type locality. A careful count in 1991 yielded 213 individuals (stems). A series of annual population counts would be needed to evaluate if the population is declining or stable.

Thirteen Botrychium ascendens plants were seen in an atypically xeric meadow ca. 1.5 air miles due south of the Hurricane Creek trailhead (Figure 17B) Four plants were seen in a very small mesic meadow ca. 1.65 air miles south of the Hurricane Creek trailhead (Figure 17C), where they are threatened by camping, fire building, and pack animal grazing and trampling. Approximately 50 plants were located by David Wagner in 1988 at the confluence of Billy Jones Creek and Hurricane Creek, along the Hurricane Creek trailhead. The writer and Ed Alverson revisited this site in 1991 (Figure 18). It is a wet to mesic meadow series. We counted 91 stems, and noted also a number of other Botrychium species. Billy Jones Creek site has good access to water and a pleasant view. It is threatened by recreational use such as camping and livestock trampling and grazing.

There is a report from D. Wagner (pers. comm.) that there is a W. Wagner photograph (circa 1983?) of B. ascendens from the Lostine Canyon, but no specimen. This record, although somewhat dubious, is mapped in Figure 16A. Two additional plants were observed on private land in 1991 in the Lostine canyon; these are mapped in Figure 16c.

Type Locality: The type locality for this recently described species is on Hurricane Creek in the Wallowa Mountains (Wagner and Wagner 1986). The type specimen is Wagner 83363 and is housed at the herbarium of the University of Michigan, Ann Arbor.
Although Wagner and Wagner (1986) state the type locality is "ca. 1.5 miles" south of the Hurricane Creek trailhead, the site is more nearly 1.2 air miles due south of the trailhead (see Figure 17A), and appears to be at the southern edge of (T3S, R44E) Section 15, not in Section 22 as commonly mapped. Ed Alverson confirmed this is the true type locality; he visited it with Herb and Florence Wagner in August 1983, and with the writer in July, 1991.

The type locality (Figure 17A) is on a large alluvial fan composed of limy fragments, in a xeric meadow east of the base of a large gray limestone cliff in the Triassic Martin Bridge formation (Walker 1977, 1979; N. Wagner 1958). The southern end of the meadow, especially near the trail, is more mesic, and is partially shaded by the patchy forest, and this is the favored site of the various moonworts at the site. Some individual plants are found on small banks and slopes incised in the alluvial fan by ephemeral rivulets. Most of the Botrychium ascendens are concentrated in two small areas, each less than 150 square meters. One is above the trail, one is below the trail. The site below the trail is reasonably flat and is used for a

campground. Here the Botrychium ascendens is endangered by indiscriminate camping, trampling and grazing of pack animals, and by campfire building.

Habitat and Associated Species: Botrychium ascendens occurs at elevations of 5250-5970 feet in the Wallowas. All known localities are on Quaternary surficial deposits, generally glacial debris reworked by modern streams. Each locality is on or near sedimentary bedrock in the Hurwal Formation or Martin Bridge Formation, and possibly the ground water is circumneutral or limy. The habitats are mesic meadows along streams or on alluvial fans, and typically have many strawberries (Fragaria virginiana). The surrounding forests are predominantly Engelmann spruce (Picea engelmannii). Colonies are in full sun, or at the south ends of meadows where they receive some shade from the nearby trees. At the wettest site, Billy Jones Cr., the meadow is marshy, but the Botrychium ascendens are on dry hummocks or mounds.

Some associates of Botrychium ascendens include:

Antennaria sp.
Calamagrostis rubescens*
Carex geyeri*
Elymus glaucus
Erigeron sp.
Festuca rubra
Fragaria virginiana*
Heuchera cylindrica
Penstemon sp.
Polygonum viviparum*
Sedum stenopetalum
Senecio pseudaureus*
Trifolium repens
Botrychium crenulatum
Botrychium lunaria
Botrychium minganense
Botrychium pinnatum
Botrychium simplex
Botrychium species "B"

* = the most numerous or dominant species

At the type locality Wagner and Wagner (1986) reported Botrychium ascendens growing with B. crenulatum, B. lunaria, and B. minganense. W. Wagner (pers. comm.) also noted finding two individuals of "Species B" at the type locality in 1983. The 1991 survey found all of the species reported by Wagner and Wagner (1986), but no individuals of "Species B".

Threats: As discussed above, all the locations in Hurricane Creek (Figures 17, 18) are threatened by recreation. The site on private land in the Lostine River basin (Figure 16C) is unprotected, and showed evidence of damage by trampling in 1991.

Recommendations: Inventories should precede any management activities in the Lostine, Wallowa, Hurricane and upper Imnaha Rivers. Heavily used recreation areas should be inventoried. Any grazing allotments in the limy portions of these basins should also be inventoried. The type locality and the Billy Jones Cr. population should be designated no camping-no grazing areas, with explanatory signs. A plan for

recreation use and limits should be drawn up for the Eagle Cap Wilderness, and it should account for the large number of rare plant species, and the fragility of their habitats. Firewood cutting and camping in the Lostine River should be restricted to areas without botanical values.

Botrychium crenulatum W. Wagner

Common Name: Crenulate moonwort

Illustrations: Figure 2, Wagner and Wagner (1981), Wagner and Devine (1989), Lorain (1990), D. Wagner (1990, 1991)

Recognition: Appendix 2, Wagner and Wagner (1981, 1986, 1990a), Wagner and Devine (1989), Lorain (1990), D. Wagner (1991)

This species remains difficult for the writer to identify, due to the similarity of its juvenile plants to forms of Botrychium simplex, B. minganense and B. lunaria. Mature plants are somewhat more frail than B. lunaria, are thinner (less fleshy) and exhibit more veins in the leaf blade. B. crenulatum leaflets are broader that those of B. minganense, and W. Wagner (pers. comm.) points out that the well-developed secondary branches on the sporophores of B. crenulatum are often helpful in identifying it. B. simplex blades are blunt apically, and do not possess the narrow, well-spaced sparse terminal segments that the fronds of B. crenulatum display.

Hybrids: A single hybrid plant of Botrychium ascendens X crenulatum was found at the type locality for B. ascendens (Wagner and Wagner 1986).

Distribution: Figure 2, Table 3

Botrychium crenulatum is also known from Arizona, Montana, Utah and Alberta (Wagner and Devine 1989). Washington State reports (Gamon, Ahlenslager, pers. comm.) from dark western redcedar (Thuja) swamps need a series of well-pressed specimens for verification. Idaho reports (Lorain 1990) are also from atypical habitat, and voucher collections have not been confirmed by W. H. Wagner to my knowledge.

This species is frequently misidentified. Oregon reports from the Blue Mts. and Steens Mt. range have proved to be incorrect. A report from Mt. Ashland in Jackson Co. Oregon may be a confusion with another species.

The only verified reports (confirmed by W. Wagner, who described the species) are from the Lostine and Hurricane drainages. 26 plants were found in the Lostine Basin, at one site (Figure 19B). One Hurricane Creek 2 populations were seen, totaling another 34 plants. Oregon's entire population is 60 individuals of this Federal candidate for endangered species status.

One of the three sites given in Table 3 is the type locality for Botrychium pedunculosum (Figure 19B). Wagner and Wagner (1986) did not report B. crenulatum there, but have confirmed (pers. comm.) the identification of plants collected during this survey (including the specimens used for the illustration in Figure 2).

There are a number of reports of Botrychium crenulatum from the Eagle Cap Ranger District in the ONHP database. Until voucher specimens of these can be examined, or the sites relocated, these are assumed to be misidentifications, and are referred to the category of "unidentified Botrychium species" (see Table 3).

Type Locality: The species was described by Wagner and Wagner (1981) from California.

Habitat and Associated Species: Crenulate moonwort grows at altitudes of 4990-5970 feet in the Eagle Cap District. The known populations are on Quaternary surficial deposits or Hurwal Formation sedimentary bedrock. All the sites may be circumneutral or limy. Botrychium crenulatum favors mesic to marshy openings, and is tolerant of partial shade but the writer has never seen it in deep shade. In mesic meadows it is found in the wettest or shadiest locations. In California it is frequently found with Botrychium simplex, in marshy mountain meadows. Botrychium simplex populations are scattered across all of Oregon's major mountain ranges (Figure 12), but occurrences of B. crenulatum remain rare.

Forest species at B. crenulatum populations are predominantly Picea engelmannii in the Hurricane basin, and Pinus contorta along the Lostine River.

Some of the associated species are presented below:

Abies grandis
Achillea millefolium
Aster sp.
Calamagrostis canadensis
Calamagrostis rubescens*
Carex concinna
Cirsium arvense
Equisetum arvense
Erigeron sp.
Fragaria virginiana*
Galium triflorum
Geum macrophyllum
Listera borealis
Picea engelmannii
Pinus contorta
Poa pratensis
Polygonum viviparum
Rumex acetosella
Senecio pseudaureus

Botrychium ascendens
Botrychium lanceolatum
Botrychium lunaria
Botrychium minganense
Botrychium multifidum
Botrychium pedunculosum
Botrychium pinnatum
Botrychium simplex
Botrychium virginianum
Botrychium species "B"

* = dominant species

Threats: The Botrychium crenulatum population at the B. ascendens type locality (Figure 17a) faces the same threats as B. ascendens. The population in the Lostine Valley (Figure 19b) is at the Botrychium pedunculosum type locality, and is threatened by firewood cutting, campfire building, piling of brush, ORV use, camping, compaction, and the possibility of hydrological changes if the nearby roads are altered.

Recommendations: Table three shows that all known populations of B. crenulatum are small. This is significant in the face of the threats to the populations. The species is a C2 candidate for the Federal endangered species list (Table 2). Priority should be given to protecting all three known Oregon sites.

Block off the road access to the Botrychium pedunculosum type locality (large boulders would do nicely and have been effective nearby), and revegetate the compacted campground with native grasses (collect seed from the vicinity). Post this area (Figure 19B) as a no camping/no firewood cutting zone. Monitor the moonwort populations. Consider prescribed fire at 7-15 year intervals to maintain the natural openings. Establish the Billy Jones Creek (Fig. 18) and B. ascendens type locality as no grazing/no camping zones, and use explanatory signs and ranger patrols to back this up. Inventory further up Hurricane Creek and in the headwaters of South Fork Imnaha River for this species.

Botrychium lanceolatum (Gmel.) Angstr. var. **lanceolatum**

Common Name: Triangle moonwort, or lance-leaved grape-fern

Illustrations: Figure 3, Hitchcock and Cronquist (1973), Cronquist et al. (1986), Lorain (1990), D. Wagner (1990, 1991)

Recognition: Appendix 2, Hitchcock and Cronquist (1973), Wagner and Wagner (1983b, 1983c, 1986), Lorain (1990), D. Wagner (1991)

Identification of this species is usually straightforward, once the silhouette illustrations have been studied. Triangle moonwort (Figure 3) is sometimes confused with juvenile forms of Botrychium virginianum (Figure 13), but the latter is much more finely dissected and is the only species in our area that regularly exhibits sterile juvenile plants. B. lanceolatum can have a warm or red-brown common stalk, but the pigmentation does not extend to the trophophore mid-vein. Many individuals lack the reddish-brown color entirely. A useful identification mark is the tendency of the lowest pinnae to angle towards the tip of the blade, even on juvenile plants.

Distribution: Figure 3, Table 3

The species (our variety) is circumboreal, in North America ranging from Alaska, Washington and Idaho east to Maine. Cordilleran populations occur south to Colorado, New Mexico, Utah and Arizona.

It has not yet been located in California (Wagner and Devine 1989). Figure 3 shows it is an east-side species in Oregon, with the exception of a reported photograph from Crater Lake National Park in Klamath Co. (D. Wagner, pers. comm.).

In the Eagle Cap Ranger District 11 populations are known, with a total of 400+ plants. These are distributed in the headwaters of the Wallowa River (Ice Lake, Fig. 21) and the East Fork of the Wallowa River (Fig. 22). Neither of these sites were seen in 1991. All the remaining localities are in the Lostine drainage, below the wilderness boundary (Figs. 16A,D,E; 19A,B,C; 20A,B,C). The largest known population for the species in Oregon is at the type locality for Botrychium pedunculosum, where there are an estimated 200-300 individuals (Fig. 19B). Most other sites have fewer than 25 plants (Table 3). Any site with more than 25 plants should be considered significant (i.e., populations mapped at Figs. 16A,E and 19B)

Habitat and Associated Species: Between elevations of 4990 and 7900 feet there are documented populations of Botrychium lanceolatum in the Eagle Cap Ranger District. Most sites are on Quaternary surficial deposits, on or near limy bedrock in the Hurwal or Martin Bridge Formations. But this species is clearly not a calciphile over much of its circumboreal range, and there is one site (Fig 22) on the East Fork Wallowa River where it has been collected on granitic-based soils derived from the Wallowa batholith. The habitats for the species are most commonly mesic meadows, with lots of strawberries (Fragaria virginiana), in open forests of Pinus contorta or Picea engelmannii. However, the site at Ice Lake is a subalpine meadow (Fig. 21). [In the Steens Mt. range B. lanceolatum is found between 8000 and 9000 feet, among scrub willows in damp ground in alpine cirques.] In places in the Lostine River valley, B. lanceolatum grows in the partial shade of trees at the edges of meadows, or even in open stands of trees (usually Pinus contorta), but it was never observed in deep shady sites where most vascular plants are suppressed by the lack of sunlight. Thus it would not be expected in Thuja swamp habitats that support B. minganense and B. montanum in the Cascade Mts. One site (Fig. 19C) is unusually marshy, but the B. lanceolatum plants are on dry hummocks, and the population is small (2 plants).

Some of the associated species recorded in 1991 are:

Abies grandis
Achillea millefolium
Agrostis sp.
Anaphalis margaritacea
Antennaria rosea
Calamagrostis rubescens*
Carex geyeri*
Elymus glaucus
Fragaria vesca
Fragaria virginiana*
Hieraceum albiflorum
Hypericum formosum
Linnaea borealis
Picea engelmannii
Pinus contorta
Ranunculus uncinatus
Sedum stenopetalum
Senecio pseudaureus
Spiraea sp.
Vaccinium scoparium
Viola adunca

* = dominant species

Botrychium ascendens
Botrychium crenulatum
Botrychium lunaria
Botrychium multifidum
Botrychium minganense
Botrychium paradoxum
Botrychium pedunculosum
Botrychium pinnatum
Botrychium simplex
Botrychium species "A"
Botrychium virginianum

Threats: Recreation and firewood cutting threatens this species at the type locality for B. pedunculosum (Fig. 19B), as described under B. crenulatum. This is the largest population for lance-leaved grape-fern in Oregon, and this is yet another reason for the Forest Service to protect this site.

Most of the sites along the Lostine River are threatened by unregulated firewood cutting, brush piling, plant succession, grazing of pack animals, camping, trampling, erosion and compaction.

Recommendations: The three large populations in the Lostine Valley, (Bowman Tr., Fig. 16A; B. pedunculosum type locality, Fig. 19B; French Camp, Fig 16E) should be protected by the Forest Service from camping, grazing, and firewood cutting. Signs should be posted explaining this, and areas already denuded of vegetation should be seeded with native meadow species, using seed collected in the Lostine Valley. Fire should be considered as a management tool if plant succession is threatening the Botrychium habitats.

Botrychium lunaria (L.) Swartz

Common Name: moonwort, or common moonwort

Illustrations: Figure 4, Hitchcock and Cronquist (1973), Cronquist et al. (1986), Lorain (1990), Wagner and Wagner (1990b), D. Wagner (1990, 1991)

Recognition: Appendix 2, Wagner and Wagner (1983b, 1986, 1990a), Lorain (1990), D. Wagner (1991)

The nomenclature used in the standard manuals for our area have confused the identification of this species (Alverson 1985). Often specimens of Botrychium minganense or B. simplex are confused with B. lunaria. Mature plants of common moonwort have a fleshy blade with broad segments that tend to overlap. Rarely B. minganense has a few slightly overlapping segments (Wagner and Devine 1989, some Steens Mt. plants, PZ obs.), but lacks the thick texture. Typically B. minganense segments are narrower and much more separated than B. lunaria. Other differences are presented in Wagner and Lord (1956), but it should be remembered that shade forms of B. lunaria are none-

the-less difficult to separate from B. minganense (Clausen 1938, Morton 1952, Cody and Britton 1989, Cronquist 1991). The short common stalk and elongated sporophore of Botrychium simplex should serve to separate its poorly developed juvenile forms from B. lunaria.

Botrychium crenulatum can be confused with B. lunaria. The former has fewer segments, which do not overlap, are relatively thin-textured, and the terminal segments are sparse, thin and well-separated. See the key in Appendix 2, and Wagner and Wagner (1981).

Distribution: Figure 4, Table 3

Botrychium lunaria has a circumboreal range in the northern hemisphere, and is found in cold-temperate areas in South America. In the United State it occurs in Alaska, Washington, Minnesota, Michigan, New York and Maine. Literature reports from other states to the south are uncertain, because of confusion with B. minganense, commonly treated as a variety of B. lunaria. For example, Munz and Keck (1965) and Lorain (1990) listed Botrychium lunaria from California, but Wagner and Devine (1989) did not.

In Oregon there are no verified reports of common moonwort outside of the Wallowas (Fig. 4), where it is present in only two drainages (Table 3). Reports from the Cascades, Blues, Mt. Ashland and Steens Mts. are all based on misidentifications of other species, usually B. minganense or B. simplex.

Two B. lunaria sites were seen in the Lostine drainage in 1991, but there were only a total of 3 plants found (Fig. 16C,E). Two other reports from the Lostine River exist, but were not found in 1991 (Figs. 16B, 19B).

Two populations were seen along Hurricane Creek in 1991, with a total of 33 plants. These are the only significant populations in Oregon, and should be protected by the Forest Service. They are at Billy Jones Creek (Fig. 18) and the type locality for B. ascendens (Fig. 17A).

Habitat and Associated Species: In Oregon Botrychium lunaria grows from 4990 to 5970 feet in elevation. It is found on Quaternary deposits or on Hurwal Formation sedimentary bedrock. These areas are on or near limy bedrock, and may all be influenced by circumneutral or limy ground water. The two largest populations, on Hurricane Creek, are on reworked alluvial fans which may be infrequently flooded. The sites are all mesic or damp meadows, with some partial shade or full sun, in open forests of Picea engelmannii, or along the Lostine River, Pinus contorta.

Some of the associated species are provided below:

Achillea millefolium	Calamagrostis rubescens
Agropyron dasystachyum	Carex concinna
Anemone drummondii	Carex norvegica

Fragaria virginiana*
Hedysarum boreale
Hieraceum sp.
Listera borealis
Picea engelmannii
Pinus contorta
Potentilla fruticosa
Potentilla gracilis
Senecio pseudaureus*
Stipa occidentalis
Symphoricarpos sp.

Botrychium ascendens
Botrychium crenulatum
Botrychium lanceolatum
Botrychium minganense
Botrychium multifidum
Botrychium pedunculosum
Botrychium pinnatum
Botrychium simplex
Botrychium species "A"

* = dominant species

Threats: The two largest populations in Oregon (Billy Jones Cr. & Botrychium ascendens type locality) are on Hurricane Cr. (Figs. 17A, 18), and both are threatened by recreational activities and pack animal grazing, as discussed under B. crenulatum. Small B. lunaria populations on Lostine River, below the Eagle Cap Wilderness boundary, are threatened by camping, trampling, firewood cutting, compaction, erosion, campfire rings, vehicle use and road maintenance or widening. The Lapover Ranch population (Fig. 16C) is private land and is not protected. This species has no secure populations in Oregon. If a reported site in the Baker Resource Area is correctly identified (Fig. 4), it is threatened by a timber sale.

Recommendations: Both sites on Hurricane Creek (Billy Jones Cr., Fig. 18; Botrychium ascendens type locality, Fig. 17A) should be designated botanical reserves, and posted as no camping/no grazing zones. The sites along the Lostine River at French Camp (Fig 16E) and the B. pedunculosum type locality should also be protected as botanical areas, blockaded from vehicles, campers and firewood cutters, posted, and monitored. More inventory is needed for this species in the upper Hurricane Cr. and South Fork Imnaha River valleys, where the ground water or bedrock is limy.

Botrychium minganense Victorin

Common Name: Mingan moonwort, gray moonwort

Illustrations: Figure 5, Wagner and Lord (1956), Hitchcock and Cronquist (1973), Cronquist et al. (1986), Wagner and Wagner (1990a, 1990b), Wagner and Devine (1989), Lorain (1990), D. Wagner (1990, 1991), Farrar and Johnson-Groh (1991)

Recognition: Appendix 2, Wagner and Lord (1956), Wagner and Wagner (1986, 1990a), Wagner and Devine (1989), Lorain (1990), D. Wagner (1991).

See the discussions under B. ascendens, B. crenulatum, and B. lunaria for ways to distinguish them from B. minganense. Botrychium montanum is also confused with B. minganense, but the latter has very regular

and evenly spaced segments, while the former has irregularly shaped and spaced segments. Both can be gray-green, and can grow side by side, so habitat cues will not help differentiate them.

There are a number of recently described eastern taxa (campestre, gallicomontanum, mormo, pallidum, spathulatum) that are difficult to separate from B. minganense, which is treacherously variable itself. The writer can not comment on them without studying living plants and type collections.

Botrychium minganense is similar to the recently discovered unnamed species "B." The latter has very slender pinnae and the trophophore is erect and clasps the sporophore at maturity, while the former has segments as broad as long and spreading blades at maturity.

Many misidentified specimens of B. lunaria and B. crenulatum are B. minganense.

Distribution: Figure 5, Table 3

As currently defined, this taxon is endemic to North America, but it is wide-ranging across Canada, from coast to coast. In the U.S. it grows in Alaska, Washington, California, Arizona, Idaho, and east to Michigan and Vermont. It is probably widespread in the western mountains, and many colonies are probably overlooked.

Oregon has a number of populations outside of the Wallowa-Whitman N.F. (Fig. 5), but many of these are threatened by logging of riparian zones. The Eagle Cap District has 14 verified sites, but most of these are small populations, with fewer than 10 individuals (Table 3, Figs. 16C, 17A, 18, 19B, 20A,D 23, 24A,B, 25, 26A, 27A). Small stations are in the following drainages: Bear Creek, Lostine River, Hurricane Creek, Wallowa River, Catherine Creek, and North Fork Imnaha River. The largest colonies are at Shady Camp, Lostine River (Fig. 20B) and S. Fk. Imnaha River (Fig. 27B), with 10-20 and 50 plants respectively in 1991. The total number of known individuals in the Eagle Cap Ranger District is 111 plants.

A number of the unidentified Botrychium (Table 3) from the Eagle Cap Wilderness will probably be B. minganense, and might add another 5-6 sites and ca. 40 plants to the current total.

Habitat and Associated Species: Verified Botrychium minganense grows at elevations of 4990 to 7000 feet in the Wallowas. Botrychium reports from 9000 feet elevations may also prove to be this fern. The species is not tied to any bedrock type, with populations found on Quaternary surficial deposits, Hurwal sedimentary rocks, Martin Bridge limestone, and Columbia River basalts. It has not yet been reported on granitic rocks in the Wallowas. Mingan moonwort is most commonly found in mesic meadows, in sparse or sometimes dense herbaceous vegetation, usually in association with strawberry (Fragaria virginiana). It tolerates light shade or dense shade, but is most easily observed in sunny situations with sparse vegetation. It can grow in damp or mesic sites, but does not seem to favor the

wetter sites where it is collected in the more southern and/or arid mountains of the west. In the Cascades of Oregon and Washington it also grows in wet sites, densely shaded by western redcedar (Thuja plicata). Alpine colonies of the species are above 8000 feet in the Steens Mountains, in wet habitats among willow shrubs. There are many possible habitats for this species in the Wallowas that have not been inventoried.

Mingan moonwort was disclosed at a number of new sites during this survey. It may be overlooked in a number of meadows in the more remote parts of the wilderness. This does not imply there are vast numbers of secure populations, as the species often grows in tiny populations (fewer than ten individuals). This species occasionally grows without other Botrychium associates.

Associated species are diverse, and include:

Abies grandis
Abies lasiocarpa
Achillea millefolium
Agrostis hyemalis
(Amanita vaginata)
Anaphalis margaritacea
Antennaria sp.
Arnica sp.
Aster sp.
Astragalus canadensis
Bromus carinatus*
Calochortus eurycarpus
Castilleja miniata
Calamagrostis rubescens
Carex hoodii
Carex raynoldsii
Dactylis glomerata
Elymus glaucus*
Erigeron coulteri
Erigeron peregrinus
Equisetum arvense
Festuca rubra*
Fragaria virginiana*
Fragaria vesca
Gentiana amarella
Geranium viscosum
Geum macrophyllum
Hackelia micrantha
Luzula campestris
Mertensia paniculata*
Picea engelmannii
Pinus contorta
Poa pratensis
Populus trichocarpa
Pyrola secunda
Ranunculus uncinatus
Ribes lacustre
Rudbeckia occidentalis
Rumex acetosella
Senecio pseudaureus*
Symphoricarpos oreophilis
Thalictrum occidentalis
Vaccinium scoparium
Viola sp.

Botrychium ascendens
Botrychium crenulatum
Botrychium lanceolatum
Botrychium lunaria
Botrychium multifidum
Botrychium montanum
Botrychium pedunculosum
Botrychium pinnatum
Botrychium simplex
Botrychium species "B"
Botrychium virginianum

* = dominant species

Threats: So many of the populations are small (less than ten individuals) that they are vulnerable to disturbances such as trampling and grazing by pack animals. Camping, compaction, erosion, firewood cutting, campfire rings, and succession may threaten other sites. Sheep grazing threatens the largest population in the Wallowas, on the S. Fk. Imnaha River (Fig. 27B).

Recommendations: Prohibit sheep grazing on the south side of the S. Fk. Imnaha River, and gradually phase out grazing in the headwaters of the Imnaha, to protect the numerous rare plant colonies there. More inventory is needed in the upper Imnaha, and some significant wetland communities there may be worthy of Research Natural Area status.

Botrychium montanum W. Wagner

Common Name: mountain grape-fern

Illustrations: Figure 6, Wagner and Wagner (1981,), Wagner and Devine (1989), Lorain (1990), D. Wagner (1990, 1991)

Recognition: Appendix 2, Wagner and Wagner (1983, 1986), Wagner and Devine (1989), Lorain (1990), D. Wagner (1991)

In our area this species can be confused with B. minganense when juvenile plants are present. It has distinctive pinnae when well-developed, see the key in Appendix 2. Small B. montanum can also show the steeply ascending pinnae that might confuse it with B. ascendens, but the former is a gray-green species while the latter is green or yellow-green.

The eastern species B. campestre and B. mormo can look very similar to B. montanum. The writer can not comment on this without studying types and living plants. See Wagner and Wagner (1981).

The broad irregular segments, often fused, and often decurrent with a wide rachis are useful field marks for Botrychium montanum. The terminal segment tends to be wide as well.

Distribution: Figure 6, Table 3.

This species is endemic to North America. Populations are documented from Montana, Washington, California, and British Columbia. A number of recent finds were made on Mt. Hood and in Washington State. In the Wallowas, a single site, E. Fk. Wallowa River Dam (Fig. 24A) is known. It was discovered in 1991 during this survey, and has 9 plants.

There are reports of this species from the Baker Resource Area, but not all of them are well-documented yet, and all appear to be threatened by timber sales.

Type Locality: Montana (Wagner and Wagner 1981)

Habitat and Associated Species: In the Eagle Cap Ranger District, this species is found at 5800 feet, on Columbia River basalt, near some limestone. It is in mesic, open woods, with sparse vegetation dominated by strawberries (Fragaria virginiana), partially shaded by Engelman spruce (Picea engelmannii). Elsewhere in Oregon and the west this species is most commonly found in dark wet, heavily shaded duff with little vegetation, under western redcedar (Thuja plicata). The Wallowas colony is atypical, but not unexpected (Wagner and Wagner 1981).

Some of its associates in the Wallowas are:

Arnica sp.
Carex rossii
Epilobium angustifolium
Fragaria virginiana*
Picea engelmannii
Pyrola secunda
Ribes lacustre
Taraxacum officinale

Botrychium minganense
Botrychium pinnatum

* = dominant species

Threats: This site is threatened by trampling, camping, compaction, exotic weeds and grazing of pack animals during the hunting season. It is susceptible to disturbances because of the small number of individuals, which are concentrated in a small area.

Recommendations: Inventory for more populations to determine status in Wallowas and elsewhere in Oregon.

Botrychium paradoxum W. Wagner

Common Name: paradox moonwort

Illustrations: Figure 8; Wagner and Wagner (1981), W. Wagner et al. (1984), Lorain (1990)

Recognition: Appendix 2, Wagner and Wagner (1983b, 1986)

This species is supposed to be unique with twin sporophores and no trophophore. However, rare shaded specimens of Botrychium minganense or B. montanum may simulate B. paradoxum. The third is distinctive in its gray-green color, equal and erect primary branches, and generally suppressed secondary branching.

Note that all species of Botrychium, even members of other subgenera such as B. virginianum, can bear marginal sporangia on the "sterile" blade, and thus there are many false reports of B. paradoxum. Some of the species commonly showing marginal sporangia on the trophophore are B. ascendens, B. pedunculosum and B. minganense. During this survey the condition (supernumerary sporangia) was also observed, but rarely, on B. crenulatum, B. lanceolatum, B. montanum, B. multifidum, B. pinnatum, and B. species "B". A careful examination of even the most extreme examples of fertile trophophores reveals the broadened lamina, which distinguishes them immediately from Botrychium paradoxum.

Distribution: Figure 8, Figure 16A

Botrychium paradoxum is "one of the rarest species in the genus" (Wagner et al. 1983). Currently it is known from Alberta, Montana, and Utah. Recent reports of the species from Washington State have not been verified (Gamon, pers. comm.)

The discovery of this species in Oregon (by Ed Alverson and the writer) during this survey adds a new fern to the flora of Oregon. There is only one station, at the mouth of Bowman Cr. along the Lostine River (Figure 16A), and the population consists of only three plants (Table 3).

Type Locality: Montana (Wagner and Wagner 1981)

Habitat and Associated Species: The Bowman site is at 5250 feet in elevation, on Quaternary surficial deposits adjacent to (limy?) sedimentary bedrock in the Triassic/Jurassic Hurwal Formation. The microsite is a S-facing bank on an alluvial fan, on dry soil. It is in sun for most of the day, but receives partial shade in late afternoon from the steep canyon wall and from scattered Pinus contorta in the area. There are a series of small openings along the parallel alluvial fans here, and they support other rare Botrychium species , including one of three U.S. stations for B. pedunculosum.

Outside of Oregon, paradox moonwort has been reported from deep shade under fireweed (Epilobium angustifolium), or in sunny meadows.

The associates observed here include:

Anaphalis margaritacea
Antennaria sp.
Carex geyeri*
Fragaria virginiana*
Hieraceum albiflorum
Hypericum formosum
Pinus contorta
Sedum stenopetalum
Spiraea sp.
Botrychium lanceolatum
Botrychium pedunculosum
Botrychium pinnatum
Botrychium simplex
Botrychium species "A"

* = dominant species

Threats: The small size of this population makes it vulnerable. It is close to a busy trailhead (Fig 16A). Grazing, trampling, camping, and exotic weeds are potential threats.

Recommendations: Perhaps because of the somewhat xeric site, this species was completely withered and absent in early August. Future inventories for the species are needed, and should be conducted in July. Because this species is a Federal C2 candidate for the endangered species list, and there are no other known Oregon localities, this site should be designated and posted as a no camping/no grazing zone. Or alternatively, signs could be posted along the Lostine River Road stating that camping and grazing are allowed only in designated areas. The Bowman site is not in the Eagle Cap Wilderness, but is on Forest Service land. The Forest Service should start monitoring use patterns on trailheads like the Bowman Tr., to determine acceptable levels of use, and the impact of that use on other resources, such as rare plants.

Botrychium pedunculosum W. Wagner

Common Name: stalked moonwort

Illustrations: Figure 9, Wagner and Wagner (1983, 1986), Lellinger (1985), D. Wagner (1990, 1991)

Recognition: Appendix 2, Wagner and Wagner (1983, 1986), Lorain (1990), D. Wagner (1991)

Botrychium pedunculosum is a distinctive member of the genus. It combines several trends: gray-green color, reddish striped common stalk and blade midvein (undersurface), frequent marginal sporangia on the blade,an ample sporophore, generally with three main axes, and stubby, angular segments that commonly overlap. It is sometimes confused with B. pinnatum, which has a reddish brown base to its common stalk, but a sessile blade, and a green, not gray-green frond. The red-brown pigment can also occur on some individuals of B. virginianum (Fig. 13) and B. lanceolatum (Fig. 3). As with B. pinnatum (Fig. 10), these species all differ from B. pedunculosum because the red coloration does not extend all the way up the common stalk and along the undersurface of the midvein of the blade.

At least two plants of B. pedunculosum showed extreme reduction of the trophophore, where the lamina was largely replaced by sporangia, suggesting the hybrid between B. hesperium and B. paradoxum called B. X watertonense (Wagner et al. 1983). These plants are among a large population of otherwise normal B. pedunculosum at the type locality (Fig. 19B). In the absence of both of the parents of the hybrid, it seems certain that these plants are merely extreme examples of the species' tendency to bear marginal sporangia on the blade. No collections were made of these unusual plants.

W. Wagner has collected a hybrid between B.pedunculosum and B. pinnatum from the type locality on the Lostine River (Wagner and Wagner 1986).

Distribution: Figures 9, 16A,E, 19B; Table 3

This species is globally rare. In Canada it is recorded from British Columbia and Saskatchewan, and there the populations are all small (Wagner and Wagner 1983). The United States has only the type locality in the Wallowa Mts. (Fig 19B), and two adjacent sites located during this survey Figures 16A, 16E).

Due to its extreme rarity, and immediate threats to the U.S. populations, the species is currently a C2 candidate for the federal endangered species list. All known U.S. sites are on the Lostine River, on lands administered by the Eagle Cap Ranger District.

The type locality has a vigorous population of 272 plants (Table 3). The French Camp colony (Fig. 16E) has 13 plants, and the Bowman Cr. station (Fig. 16A) supports 6 plants. The United States total is less than 300 plants.

A population of 34 Botrychium pedunculosum was reported from Washington State in 1991, but the record is not verified (Gamon, Ahlenslager, D. Wagner, pers. comm.), may be another species, and is threatened by logging.

Type Locality: Wagner and Wagner (1986) give the type location as "1.6 mi S of ranger cabin, 13.3 mi S of Lostine Church, grassy second-growth area along road, Lostine River Valley, Wallowa Co., Oregon." The holotype specimen (Wagner 83361) is deposited at MICH, the University of Michigan herbarium at Ann Arbor.

A paratype is also given in Wagner and Wagner (1986): "1.2 miles N of Bowman Trail, Lostine River Valley, Lostine River Valley, Wallowa Co., Wagner 81330 (MICH)," implying a second locality. Studying the map distances on Figures 16 and 19, it can be shown that the paratype and holotype are the same place, i.e., 1.2 miles N of the Bowman Trail is the same as 13.3 miles S of Lostine Church. This was confirmed repeatedly with an odometer during this survey. D. Wagner also pointed this out to the writer. W. Wagner and F. Wagner (1986) were in error when stating the holotype locality is 1.6 miles south of the ranger cabin. The guard station/ranger cabin is 1.3 miles from the type locality. This was confirmed by Ed Alverson, who visited the type locality with the writer and with W. and F. Wagner in 1983.

A large marsh with very few Botrychium is found at 1.6 miles S of the guard station. No habitat for (and no plants of) B. pedunculosum have ever been located 1.6 miles S of the ranger cabin. Forest Service and ONHP files should be corrected to reflect this.

The type locality consists of a series of small openings and old stream channels, several of which have colonies of B. pedunculosum,

for a north-south stretch of at least 0.2 miles between the Lostine River and the Lostine River Road. A well-defined pullout (1.3 miles south of the guard station) and campground marks the southern extent of the population.

Habitat and Associated Species: The Lostine River populations of stalked moonwort are found between altitudes of 4990 and 5340 feet. Each is on Quaternary surficial deposits. Two of the three sites are close to sedimentary rocks of the Hurwal Formation, which may be limy. Large parts of the east wall of the Lostine Canyon are composed of pure limestone of the Martin Bridge Formation type, and it is possible that all of the sites are influenced by circumneutral or calcareous ground water percolating through limy bedrock, limy glacial till, or morainal debris.

All three sites are in open stands of lodgepole pine (Pinus contorta), among low herbaceous growth, most commonly strawberries (Fragaria virginiana). Each site receives some shade early and late in the day due to the steep canyon walls, but the plants are in relatively sunny positions in the small forest openings. Soil moisture varies, averaging mesic. French Camp site is mesic. A south-facing bank at Bowman is dry by mid-summer, and plants there do not last much beyond mid-August before wilting. In contrast low damp channels in abandoned oxbows at the type locality support dense grasses and there the B. pedunculosum persists well into September.

Some associated plants:

Abies grandis
Achillea millefolium
Agrostis sp.
Antennaria rosea
Antennaria sp.
Astragalus alpinus*
Bromus sp.
Calamagrostis rubescens*
Danthonia intermedia
Festuca rubra*
Fragaria vesca
Fragaria virginiana*
Gentiana amarella
Hieraceum sp.
Luzula campestris
Picea engelmannii
Pinus contorta
Poa pratensis
Potentilla gracilis
Senecio pseudaureus*
Smilacina stellata
Stipa lettermannii
Veronica serpyllifolia

Botrychium crenulatum
Botrychium lanceolatum
Botrychium lunaria
Botrychium multifidum
Botrychium paradoxum
Botrychium pinnatum
Botrychium simplex
Botrychium species "A"
Botrychium virginianum

* = dominant species

Threats: All the populations of this species are threatened by camping, compaction, erosion, trampling, pack animal grazing, exotic weeds, firewood cutting, campfire rings, at French Camp and the type locality, ORV use by hunters or firewood cutters is a potential threat.

Recommendations: All three American locations for Botrychium pedunculosum should be established as botanical preserves, and the areas should be designated, no camping/no grazing zones. The access road at the type locality (Fig. 19B) should be blocked with large rocks. This has worked on other road closures in the valley. Signs at all three areas should explain why grazing and camping are no longer allowed. An effective new policy would be to limit grazing, firewood cutting, camping, etc. in the Lostine Valley to designated sites. The sites should be chosen only after a good botanical inventory, since the canyon floor supports a number of rare Botrychium and Listera borealis in the open areas favored for recreational use.

Botrychium pedunculosum needs more survey work. The majority of the west side of the Lostine River is unexplored, and may yield more sites. At present, the species should be monitored to determine if the populations are stable, increasing or decreasing. Recreational and firewood cutting use in the Lostine Valley should also be more closely monitored. The data suggest a change from C2 to C1 status is warranted if no new sites are located.

Botrychium pinnatum St. John

Common Name: pinnate grape-fern, northern moonwort

Illustrations: Figure 10, Hitchcock and Cronquist (1973, as B. boreale), Wagner and Wagner (1983c), Lorain (1990), D. Wagner (1990, 1991)

Recognition: Appendix 2, Mason (1980), Cronquist et al. (1986), Wagner and Wagner (1983b, 1983c, 1986), Lorain (1990), D. Wagner (1991)

See the discussion under Botrychium pedunculosum for the means to distinguish it from B. pinnatum. The latter is a fairly distinctive species, long known from the Pacific Northwest, and treated in most older manuals as B. boreale, which is currently understood to be restricted to the old world.

Small plants of Botrychium lanceolatum are sometimes confused with B. pinnatum, but the former differs in its cutting and in the upwards angling basal pinnae (compare Figs. 3 and 10).

Some eastern grape-ferns can be easily confused with Botrychium pinnatum. The writer, unfamiliar with the types or living populations at present, can offer little advice beyond distinctions of range for these taxa: B. acuminatum, B. echo, B. hesperium, B. matricariifolium, and B. pseudopinnatum. This group, and the eastern hemisphere B. boreale, form a complex series. Wagner and Wagner (1983b, 1983c, 1990b) discuss the intricacies.

Distribution: Figure 10, Table 3

This species is known from Alaska, Montana, Nevada, Idaho, and Washington. In Canada it has been collected in British Columbia, Yukon Territory, and Alberta. Despite its wide range, the species is rather rare and local.

Figure 10 shows the county distribution in Oregon. It is found in east-side mountain ranges, with the exception of 1-2 tiny colonies on Mt. Hood, in the Little Badger Cr. Wilderness. Sites in Baker and Union Cos. were confirmed by the writer during this inventory. Harney County populations were also visited in 1991.

The populations in the Wallowas (Table 3) are small, with a total 12 sites and 158 individuals. Half the stations are comprised of fewer than 15 plants. The species has been documented from only three drainages to date. The majority are in the Lostine Canyon, two are in the Wallowa River headwaters, and a single site was discovered in the Imnaha headwaters during this inventory. Any population with 15 or more plants should be considered significant. Five such colonies are in the Lostine River (Figs. 16A,C, 19B, 20A,D) and one is in the Imnaha drainage (Fig. 27B).

Habitat and Associated Species: The summary in Table 3 shows northern moonwort occurs at elevations of 4990-7000 feet. It, like Botrychium minganense and B. lanceolatum, grows on a wide variety of substrates, such as Quaternary surficial deposits near Hurwal sedimentary rock, Columbia River basalts, and on granitic intrusives. It is clearly not a calciphile, although the most vigorous populations are in limy basins (Lostine and Imnaha). Most plants were found in mesic meadows, with sparse to dense grasses and low herbaceous cover. Some plants were in partial shade, among open stands of Pinus contorta or Picea engelmannii.

Some of the associates noted during the inventory were:

Abies grandis
Abies lasiocarpa
Achillea millefolium
Agrostis hyemalis
Alnus sp.
Antennaria sp.
[Amanita vaginata]
Arnica sp.
Aster sp.
Bromus sp.
Calamagrostis rubescens
Carex geyeri*
Elymus glaucus*
Erigeron coulteri
Festuca rubra
Fragaria vesca*
Fragaria virginiana*
Gentiana amarella
Geum macrophyllum
Hieraceum albiflorum
Mertensia paniculata
Picea engelmannii
Pinus contorta
Potentilla fruticosa
Ranunculus uncinatus
Sedum stenopetalum
Senecio pseudaureus*
Smilacina stellata
Symphoricarpos sp.
Rudbeckia occidentalis
Thalictrum sp.*
Vaccinium scoparium
Viola sp.*

* = dominant species

Botrychium ascendens
Botrychium crenulatum
Botrychium lanceolatum
Botrychium lunaria
Botrychium multifidum
Botrychium paradoxum
Botrychium pedunculosum
Botrychium simplex
Botrychium species "A"
Botrychium species "B"
Botrychium virginianum

Threats: Many of the best sites for Botrychium pinnatum are threatened by the grazing of pack animals in the Lostine Canyon, or by domestic sheep grazing in the Eagle Cap Wilderness, on the South Fork of the Imnaha River (Fig. 27B). Other threats to significant populations (15 or more plants) include camping, compaction, exotic weeds, erosion, road maintenance, firewood cutting, campfire rings. Long term threats may include plant succession from meadows and open forest to a closed canopy forest, where there are stands of Pinus contorta and there are no fires. Although B. pinnatum is relatively shade-tolerant, the shade would allow the establishment of dense stands of Vaccinium scoparium, which would eventually outcompete northern moonwort.

Recommendations: Recreation monitoring and management must be emphasized if the populations of moonworts are to survive. Establishment of no grazing/no camping zones would help. Phasing out sheep grazing in the Imnaha headwaters, and eliminating it entirely from the south side of the S. Fk. Imnaha is strongly recommended. More inventory and detailed management plans are needed for this and the other rare species (more than 20 total) growing in the canyon floors of the Hurricane, Wallowa, Lostine and Imnaha Rivers in or near the Eagle Cap Wilderness.

Other species:

Further inventory is needed to revisit the nine sites where Botrychium spp. are reported but unidentified to species (Table 3). These sites are mapped in Figures 20A,B, 21, 28A, 29A,B and 30. Inventory for Botrychium is so time-consuming that it was not possible to visit all the sites in 1991.

Illustrations are provided for all other Botrychium taxa known in Oregon, although one, B. pumicola (Fig. 11), does not grow in the Survey area. The others, B. multifidum (Fig. 7), B. simplex (Fig. 12), and B. virginianum (Fig. 13) are occasional in the Wallowa-Whitman National Forest.

Two species were located during the 1991 survey that are new to science, and have not yet received a binomial. These have been referred to as Botrychium species "A" (Figs. 14, 16A,E) and

Botrychium species "B" (Figs. 15, 16C, 17). Photocopies of pressed specimens are included in this report (Figs. 14, 15), and were sent to W. Wagner. He believes they are new species.

The writer, together with Ed Alverson, found both new species in the Lostine River canyon, where the small populations (Table 3) face numerous threats from grazing, trampling, camping, firewood cutting, etc.

There is an urgent need for more inventory for these new taxa, to determine their true distribution, abundance, and the possible need for state or federal endangered status.

Part 4. Botrychium on the Baker and LaGrande Districts

A number of new reports of Botrychium species were made outside of the Eagle Cap District in 1991. The writer does not have good maps or voucher specimens for most of these reports, and so can only give them a superficial treatment here.

The sites with verified records are those which the writer visited, or saw photocopies of pressed specimens, with the exception of B. montanum. They are as follows:

T (S)	R (E)	S	Elev ft.	Popul. stems	Site	CO	Res. Area
				Botrychium lanceolatum			
6	43	5	5450	40	W Eagle Cr.	BAKE	LaGrande
				Moderately large and sig. population			
				Botrychium montanum			
7	37	8	6920	50-100	Sand Gap TS	BAKE	Baker
				Reportedly ID ! by D. Wagner			
				Botrychium pinnatum			
4	42	30	5200	22	N Fk Cath Cr	UNIO	LaGrange
				Moderately large and sig, population			
6	37	29	5300	2	Anthony Cr	UNIO & BAKE	Baker

An additional identifiable specimen of B. simplex was seen from W. Eagle meadow in Union County (T5S R43E S32), LaGrande R.D.

One photocopy of what appears to be a Botrychium minganense was sent, with no locational data besides "Fly Creek." It was collected by Larry Noe.

Other reports were not adequately documented, and will need to be revisited late in 1992 to gather voucher collections for verification. These are listed below (no map data is available to the writer):

T	R	S	Elev	Popul.	Site	Notes
4S	41E	12	6500 ft.	2 stems	Deadhorse Flat	lunaria?
4	41	26	5200	1	L. Catherine Cr.	lunaria?
4	33	11	4650	3		montanum?
4	42	15	5950	42	Rock Cr	pinnatum? big pop
5	34	17	4800?	7	Oz/Doghair	minganense?
5	36	34	5150	20	Jim Salv 21	minganense?
6	36	3	5000	15	Muir	minganense?
6	43	5		6	Eagle 2	pinnatum?

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APPENDIX 1.

Table 1. Some Botrychium mimics in the Eagle Cap Ranger District.

Achillea millefolium
Carex aurea
Fragaria virginiana lf buds
Gentiana amarella
Linnaea borealis
Listera borealis
Listera caurina
Listera convallarioides
Listera cordata
Luzula campestris
Polygonum viviparum
Rumex acetosella
Taraxacum officinale

APPENDIX 1.

Table 2. December 1991 status of Botrychium species in Oregon.

Taxa	FWS	USFS	ODA	ONHP	Changes suggested for 1992
ascendens	C2	S	C	1	None
crenulatum	C2	S	C	1	None
lanceolatum	-	S	-	2	None
lunaria	-	S	-	2	None
minganense	-	S	-	2	None
montanum	-	S	-	2	None
multifidum	-	-	-	-	None
paradoxum S,C,1	C2	-	-	-	Add:
pedunculosum	C2	S	C	1	C1?
pinnatum	-	S	-	2	None
pumicola	C1	S	C	1	None
simplex	-	-	-	4	Drop
virginianum	-	-	-	4	Drop

Explanation of table:

FWS = U.S. Fish and Wildlife Service C2 and C1 candidates for federal endangered species status, as listed in the Federal Register (February 21, 1990, Vol. 55, No. 35)

USFS = U.S. Forest Service Region 6 Sensitive Plant List; S indicates sensitive status (March 1991)

ODA = Oregon Dept. of Agriculture's Candidate Species List; C indicates candidate status (March 1991)

ONHP = Oregon Natural Heritage Program lists (May 1991), see text

APPENDIX 1.

Table 3. Botrychium sites in the Eagle Cap Ranger District, Wallowa Co., Oregon.**

T (S)	R (E)	S	Str	Alt (ft)	Geo	Pop	Notes/Map
				Botrychium ascendens			
3	43	23	L	5250	Q,H	1+	1983 W. Wagner 16A
3	43	25	L	5250	Q,H	2	Private 16C
3	44	15,22	H	5350-5440	Q	213	Type loc. 17
3	44	33	H	5970	H	91	18
				Botrychium crenulatum			
3	43	11	L	4990	Q,H	26	19B
3	44	15	H	5330-50	Q	16	17A
3	44	33	H	5970	H	18	18
				Botrychium lanceolatum			
3	43	11	L	4990	Q,H	250+	19B
3	43	11	L	5000	Q,H	10	1988 D. Wagner 19A
3	43	14	L	5000	Q,H	2	19C
3	43	23	L	5250	Q,H	39	16A
3	43	25	L	5300	Q	10	16D
3	43	25	L	5340	Q	55	16E
3	43	36	L	5450	Q	24	20A
3	43	36	L	5480	Q	5	20B
3	43	36	L	5525	Q	6	20C
4	44	12	W	7900	H	1	21
4	45	9	W	6900	K	1+	1966 Mason 22

Table 3, cont.

T (S)	R (E)	S	Str	Alt (ft)	Geo	Pop	Notes/Map
				Botrychium lunaria			
3	43	11	L	4990	Q,H	rare	1983 W. Wagner 19B
3	43	23	L	5400	H	1+	1967 Mason 16B
3	43	25	L	5250	Q,H	2	Private 16C
3	43	25	L	5340	Q	1	16E
3	44	15	H	5350	Q	20	17A
3	44	33	H	5970	H	13	18
				Botrychium minganense			
2	42	23	B	4750	V	7	23
3	43	11	L	4990	Q,H	6	19B
3	43	25	L	5250	Q,H	7	Private 16C
3	43	36	L	5450	Q	6	20A
3	43	36	L	5480	Q	10-20	20B
3	44	15	H	5350	Q	5	17A
3	44	33	H	5970	H	2	18
3	45	33	W	5800	V	3	24A
3	45	33	W	5950	M	5+	24B
4	42	18	C	5700	V	1+	1985 ecoplot 25
4	43	1	L	5580	Q	2	20D
4	44	7,8	L	7000	Q	1+	1965 Mason 26A
5	45	25	I	5550	Q	50	27B
5	46	18	I	5220	H	1	27A
				Botrychium montanum			
3	45	33	W	5800	V	9	24A
				Botrychium paradoxum			
3	43	23	L	5250	Q,H	3	16A

Table 3, cont.

T (S)	R (E)	S	Str	Alt (ft)	Geo	Pop	Notes/Map
				Botrychium pedunculosum			
3	43	11	L	4990	Q,H	272	type loc 19B
3	43	23	L	5250	Q,H	6	16A
3	43	25	L	5340	Q	13	16E
				Botrychium pinnatum			
3	43	11	L	4990	Q,H	35+	19B
3	43	23	L	5250	Q,H	15	16A
3	43	25	L	5250	Q,H	23	Private 16C
3	43	25	L	5340	Q	4	16E
3	43	36	L	5450	Q	21	20A
3	43	36	L	5480	Q	1	20B
3	43	36	L	5525	Q	1	20C
3	45	33	W	5800	V	6	24A
4	43	1	L	5580	Q	23	20D
4	44	18,19	L	7000	K	1+	1971 Mason 26B
4	45	9	W	6900	K	1+	1966 Mason 22
5	45	25	I	5550	Q	27	27B
				Unidentified *Botrychium* sp.			
3	43	36	L	5450	Q	1	ped? 20A
3	43	36	L	5450	Q	2	sp A? 20A
3	43	36	L	5480	Q	1	lun? 20B
4	44	4	H	6000	H	15+	spp? 28A
4	44	12	W	7900	M	15	ming? 21
4	44	15	H	7000	Q	1+	ming? 28B
4	45	28	W	8000	H	15	1987 Zika 29A
4	45	33	I	7550	M	2	ming? 29B
5	45	7	W	9000	M	4	ming? 30

Table 3, cont.

T (S)	R (E)	S	Str	Alt (ft)	Geo	Pop	Notes/Map
				Unnamed Botrychium species A			
3	43	23	L	5250	Q,H	26	16A
3	43	25	L	5340	Q	2	16E
				Unnamed Botrychium species B			
3	43	25	L	5250	Q,H	15	Private 16C
3	44	15	H	5350	Q	2	1983 W. Wagner 17

** Explanation of codes in Table 1:

Str = Stream basin
B: Bear Cr., C: Catherine Cr. (N Fk.), I: Imnaha R. (N, M, S Fks.), L: Lostine R. (& E Fk.), W: Wallowa R. (E,W Fks.)

Geo = Geology (N. Wagner 1958; Walker 1977, 1979)
H: Hurwal Formation, Upper Triassic and Lower Jurassic age; marine sedimentary, mudstone, siltstone, limestone, or greenstone. Some interbedded volcanics are possible
K: Wallowa/Cornucopia intrusive batholiths, Cretaceous age; granitic (tonalite, 149 m.y.)
M: Martin Bridge Formation, Upper Triassic age; limestone or marble
Q: Quaternary surficial deposits, Pleistocene/Holocene age: alluvium, colluvium, glacial moraine, outwash; bedrock is buried at these sites
V: Columbia River Group volcanics, Miocene age; basalt

Pop = Population, counts are 1991 genets (stems) unless noted

Notes/Map = type loc: Type locality for the species
Year and name: Date of last observation and reporter
/Map: Figure # in Appendix 3; topo maps with site

APPENDIX 2.

An identification key to the Oregon species of Botrychium (Ophioglossaceae).

By Peter F. Zika
Oregon Natural Heritage Program.
February 1992.
Largely written by D. Wagner (1991).

1. Blade (trophophore, also called sterile segment, sterile lamina, "the leafy part") absent, stalk gray-green (glaucous), bearing two sporophores (also called a fertile segment, fertile lamina, bearing sporangia), these approximately the same length and erect, sporangia commonly secund, secondary branching supressed; sporophores never expanded, flattened or resembling the lamina of a blade

Botrychium paradoxum

1. Blade and sporophore present (rarely blade reduced and bearing many sporangia, but always with a flattened or widened or laminar rachis or pinna axis); plant green or gray-green; sporangia non-planar or secund, secondary branching in sporophore supressed or prominent

2. Plant evergreen, blade overwintering and persisting until (or after) the emergence of a new blade the following summer

Botrychium multifidum

2. Blades deciduous, withering in autumn

3. Blade ternate, pinnate or pinnate-pinnatifid, the lowest segment (pinna) at least partially divided and distinctly larger than upper segments; blade outline either triangular or lanceolate

4. Blade sessile or with a stalk 2-3 mm or less; common stalk sometimes extending well above ground level; plant sometimes gray-green

5. Common stalk completely buried or extending above the ground less than half the length of the blade; plant gray-green; blade ternate , the lower-most segments enlarged and well-separated from the rest of the blade (autumn foliage brown)

Botrychium pumicola

5. Common stalk extending well above the ground, at least equal to the length of the blade; epidermis bright or shiny green; blade pinnate, the segment s progressively reduced from base to tip

6. Blades bipinnate to tripinnate, usually longer than 8 cm, oriented horizontally; tips of segments sharp (rarely rounded); primary segments at right angles to axis of blade

Botrychium virginianum

6. Blades bipinnatifid to bipinnate, less than 7 cm, ascending to erect, tips of segments rounded; primary segments angled towards tip of frond

Botrychium lanceolatum

4. Blade with a stalk 5 mm or more; common stalk usually buried below ground level; plant shiny green or lightly gray-green, never heavily glaucous

7. Robust plants, blades usually more than 10 cm, fleshy, leathery, remnants of previous season's evergreen blade usually present (sometimes absent due to predation); blade pinnate, the segments progressively reduced from base to tip; common throughout the state

Botrychium multifidum

7. Small plants, blades rarely more than 7 cm, thin and deciduous (turning yellow and then brown as it fades, thus differentiating it from the similar B. pumicola), brown by mid-season,; blade ternate, the lower-most segments enlarged and well-separated from the rest of the blade

Botrychium simplex

3. Blade lanceolate in outline, the lowest segments less than half as long as the total length of the blade

8 Blade at ground level or close to it, common stalk exposed less than half the length of the blade; sporophore stalk longer than the blade

reduced forms of Botrychium simplex

8. Blade elevated on common stalk well above ground level; sporophore barely longer than blade, if at all

9. Blade sessile; plant green or shiny green; segments symmetrical, tending to be evenly spaced and progressively reduced from bottom to tip

Botrychium pinnatum

9. Blade with a short stalk; plant gray-green; segments asymmetrical at base of blade and/or overlapping

10. Undersurface of blade with reddish-brown stripe on mid-vein, stripe extending down blade stalk and common stalk to ground; lowest segments commonly with marginal sporangia, the axis of basal segments often curved-ascending

Botrychium pedunculosum

10. Reddish-brown stripe lacking; segments rarely (never?) bearing sporangia, the axis of basal segments straight

unnamed Botrychium species "A"

3. Blade once-cut (pinnate), lowest segment not appreciably larger than next segment above it and not divided (sometimes more-or-less toothed); blade strap-shaped, with more-or-less parallel sides

11. Blade at ground level or close to it, common stalk exposed less than half the length of the blade; sporophore stalk longer than the blade

reduced forms of Botrychium simplex

11. Blade elevated on common stalk well above ground level; sporophore barely overtopping blade, if at all

12. Segments of blade lunate (half-moon shaped), in outline a quarter-circle to a half-circle (or more), often overlapping in one species; sporangia rarely occurring on margin of blade

13. Segments overlapping, at least in upper part of blade; lower segments typically greater than a half-circle in outline; lower branches reduced on sporophore; blade green to dark green, often shiny, thick; veins not evident in nature; apical segments tending to be relatively broad and aggregated; segment margins crenulate (with tiny rounded teeth) to entire (smooth)

Botrychium lunaria

13. Segments separated, notably at tip of blade when pressed; lower segments mostly less than a half-circle in outline; lower branches well-developed on sporophore; blade not shiny, green to light green, relatively thin; veins evident in situ; apical segments tending to be few, narrow and well-separated; segment margins crenulate

Botrychium crenulatum

12. Segments of blade cuneate (wedge-shaped) to oblong or linear, if cuneate the wedge never as wide as a quarter-circle; segments generally well-separated; sporangia sometimes on margin of blade

14. Segments mostly perpendicular to mid-line of blade, only slightly if at all angled upwards; outer margin entire to undulate, generally untoothed

15. Ultimate segments oblong-linear to oblanceolate, two or more times long as wide; blade at maturity erect and enfolding the sporophore; plant prominently gray-green

unnamed Botrychium species "B"

15. Ultimate segments variable, often cuneate and fan-shaped, about as long as wide; blade at maturity ascending to spreading, segments not clasping the sporophore; plant slightly gray (especially in sunny situations) or green

Botrychium minganense

14. Segments decidedly angled towards tip of blade; outer margins of segments often toothed

16. Segments wedge-shaped, typically rather veiny; outer margins rounded, usually toothed or serrated; three or more pairs of segments present in mature plants; the upper ones most prominently angled towards the tip of the blade; plants yellow-green, sometimes shiny; sporangia frequent on segment margins

Botrychium ascendens

16. Segments rhombic, not veiny; outer margins truncate, not rounded, entire or at most irregularly and coarsely toothed; rarely with more than two pairs of segments; the lowest segments most prominently angled towards the tip of the blade; plants slightly gray-green (grayer than B. minganense when growing side by side); sporangia occasional on segment margins

Botrychium montanum

APPENDIX 3 Figure 1.
Botrychium ascendens
map and illustration

Botrychium ascendens

Camels Hump is one of two significant alpine plant communities in the Green Mountains of Vermont (Vogelmann 1971). On Camels Hump are two regional alpine endemics and 12 other locally rare, threatened or endangered alpine species (Thompson 1989, Crow 1982, Zika 1982, Crow et al. 1981; 10 V.S.A., Chapter 123).

There are several contemporary threats to the alpine biota on Camels Hump. Forest decline at low altitudes (Siccama et al. 1982, Johnson and Siccama 1983, Scherbatskoy an Bliss 1984, Vogelmann et al. 1988) suggests alpine s d by air pollution. Another potential impact to bc ic warming (Mitchell 1961; Callendar 1961; Lamb 197 amburg and Cogbill 1988). Finally, heavy recreat perimposes another threat.

Historical species loss in as is little studied. This paper documents the loss of ls Hump over the last 160 years.

The Study Area. Camels Hump is a 1244 m summit in the northern Green Mountains (72°53′12"W, 44° 19′11"N), 30 km southeast of Burlington, Vermont. The 5 ha above the 1160 m contour were studied. A scrub Abies balsamea forest covers 4 ha. The 1 ha summit is dominated by Carex bigelowii sedge meadow, Vaccinium uliginosum heath mats, and Abies krummholz. Exposed ledges and cliffs are common. Leffler (1981) provides climatic data. The area is part of Camels Hump State Forest and the Champlain-Adirondack Biosphere Reserve.

Methods. Between 1977-84 the extant alpine flora on Camels Hump was studied during more than 200 visits. The contemporary flora was compared with historical data from herbaria (A, BUF, GH, HNH, MASS, MO, NASC, NEBC, NY, SJFM, TUFT, US & VT) and relevant literature (Ladd 1979, Oakes 1842,

Botrychium crenulatum

Figure 2. Botrychium crenulatum map and illustration

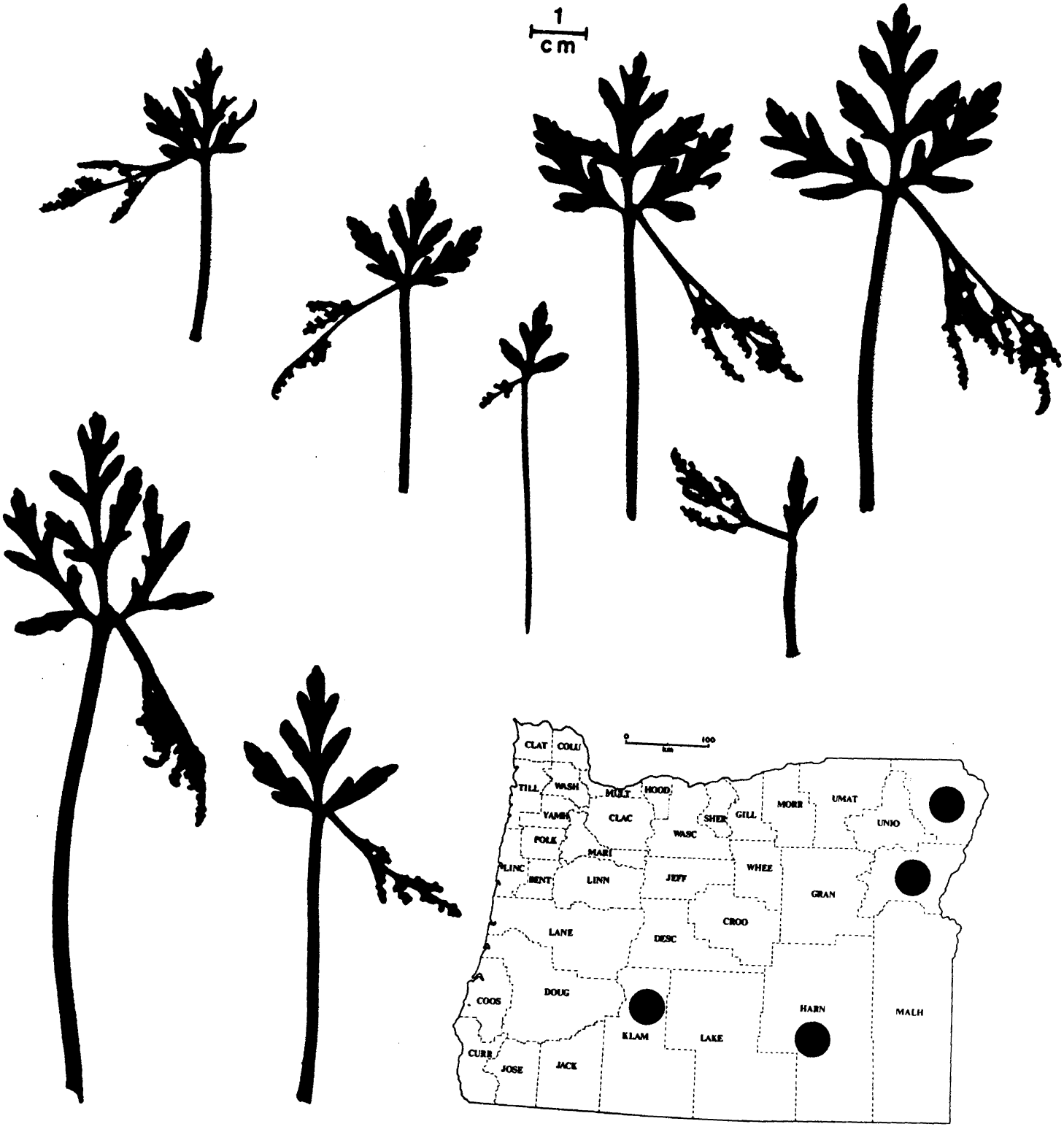
All four botanists were familiar with them from their explorations in other alpine areas.

Discussion. Did A. viridis, H. alpina, P. viviparum, and V. vitis-idaea disappear in the 1800s? Their extirpations are suggested by presence and then absolute absence data in the botanical record (Table 1). The possibility of long-persistent sterile (unrecognizable) individuals or viable dormant propagules in soil without permafrost, for more than a century, is highly unlikely. Repeated searches by many botanists in a small area renders continuous absence data reasonably certain.

What led to the implied decline and extirpation of four alpine species on Camels Hump between the 1800s and the present? On many summits rare alpine species are often restricted to small areas, resulting in an unusual vulnerability to human disturbance. Thus historical human impacts on the study area were probably important.

THE LOSS OF VACCINIUM VITIS-IDAEA AND ALNUS VIRIDIS VAR. CRISPA. Both taxa were apparently absent in 1874, 1875 and 1876, when Cyrus Pringle was studying Camels Hump, the "peak most accessible to [him]" (Pringle 1897). It is doubtful P[illegible]. Pringle collected with "vigor and thoroughness" (E[illegible]roughness of his methods" leading Asa Gray to call [illegible] collectors (Davis 1936). Dr. O. W. Barrett noted: "[illegible]ake a clean sweep'-taking specimens of all the speci[illegible]worked,' not merely 'skimming' the area for for lik[illegible]es" (Davis 1936). Pringle (1876, 1897) wrote abou[illegible]e species new to the flora of Vermont on Camel[illegible] V. vitis-idaea and A. viridis collections from [illegible] It is difficult to argue he failed to notice and collect or mention them in 1874-6 on Camels Hump. Pringle (1897) said he left Camels Hump in 1876 having completely investigated the "limited" alpine zone, and "clambered...over every shelf of its great

Figure 3. Botrychium lanceolatum map and illustration



Historical species loss in the alpine zone of Camels Hump, Vermont.[1]

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ABSTRACT

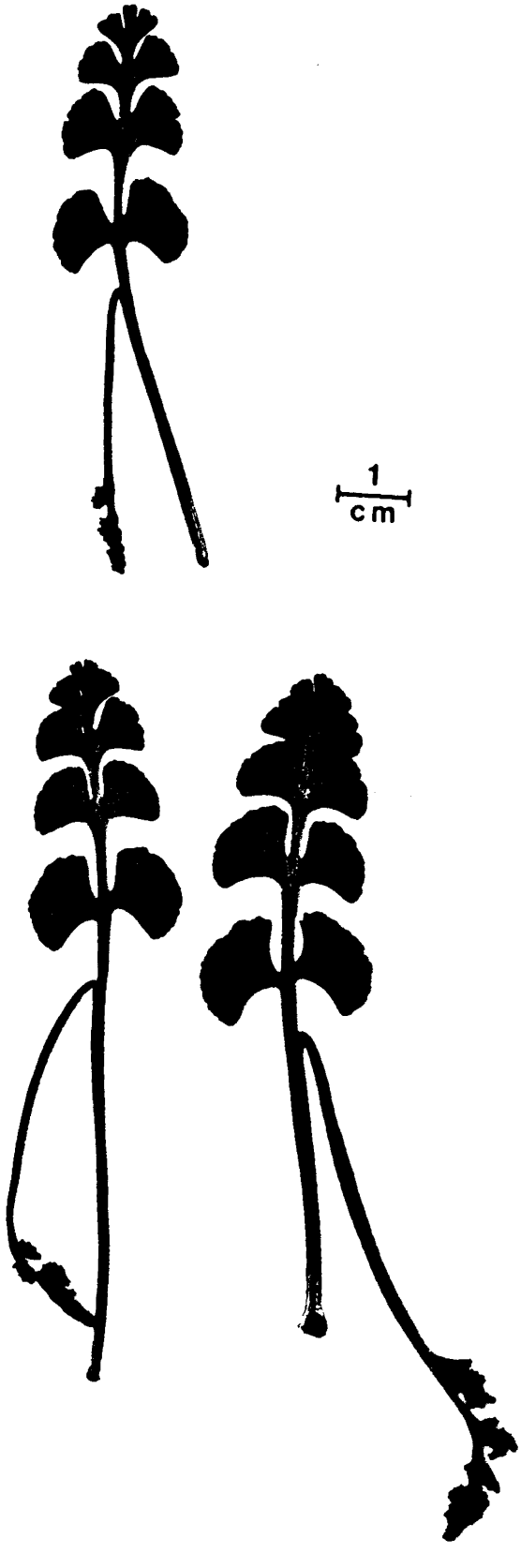
Zika, P. F. (Oregon Natural Heritage Program, 1205 NW 25th Ave., Portland, OR 97210). Historical species loss in the alpine zone of Camels Hump, Vermont. Bull. Torrey Bot. Club XXX:000-000. 19XX.--A comparison of the extant alpine flora with the historical record shows that Camels Hump is not a pristine alpine area, despite its present status as the only sizable undeveloped alpine area in Vermont. Herbarium and literature evidence suggest four alpine taxa disappeared since the first botanical survey in 1829. Alnus viridis and Vaccinium vitis-idaea vanished between 1840 and 1874. Hierochloe alpina and Polygonum viviparum were last recorded in 1876. Human disturbance and overcollecting are likely explanations for the extirpations, but climatic or other factors may have contributed. Apparently n ies immigrated this century.

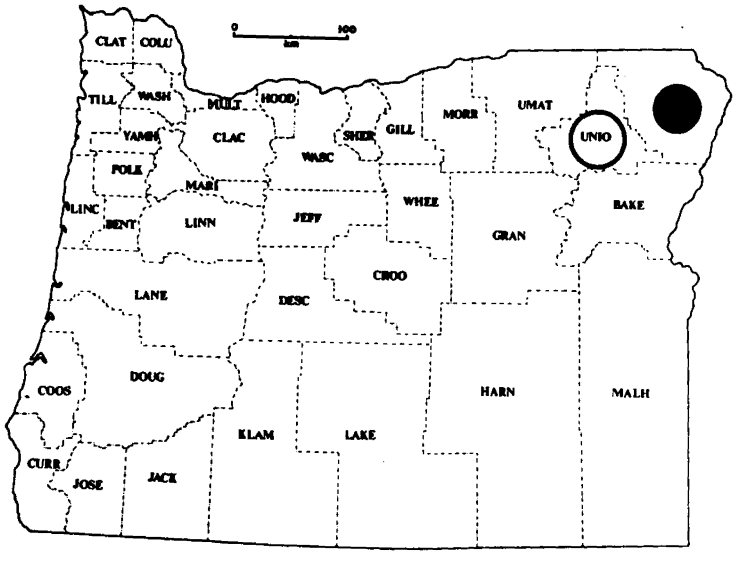
Key words: alpine flora, s Hump, disturbance, extirpations, rare species

[1] This research was ingle Herbarium, the Agricultural Experiment S of Vermont, and The Nature Conservancy.

[2] I am indebted to . Jenkins, Rose Paul, Carol Savonen, Hubert Vogelmann, and Helen Whitney for their advice or field assistance. I thank the curators of the herbaria cited, and Amherst College Archives for aid with Tuckerman's unpublished journals.

Figure 4. Botrychium lunaria
map and illustration





Droughts in 1883, 1903 and 1907 (Whitney 1988) probably came after the species were extirpated. Similarly, the 1903 fire on Camels Hump was probably not a factor in the extirpations. Hawes (1909, 1911) described the 800 ha blaze as "severe" at upper elevations, but Whitney (1988) showed it did not burn the alpine zone, where there is little fuel (Baldwin 1974).

Conclusions. Four alpine taxa (19% of the rare native alpine species in Table 1) disappeared since the first botanical survey in 1829. Successful immigration of native alpine species apparently halted this century. Preventing further reduction of biological diversity is desirable in this important natural area. The alpine meadow community, the endemics and rare species could be monitored to assess the impacts of pollution and predictions of climatic warming (e.g., Schindler et al. 1990). The data would have a wide applicability to policy makers and resource managers administering other alpine areas in the northeastern Appalachian Mts.

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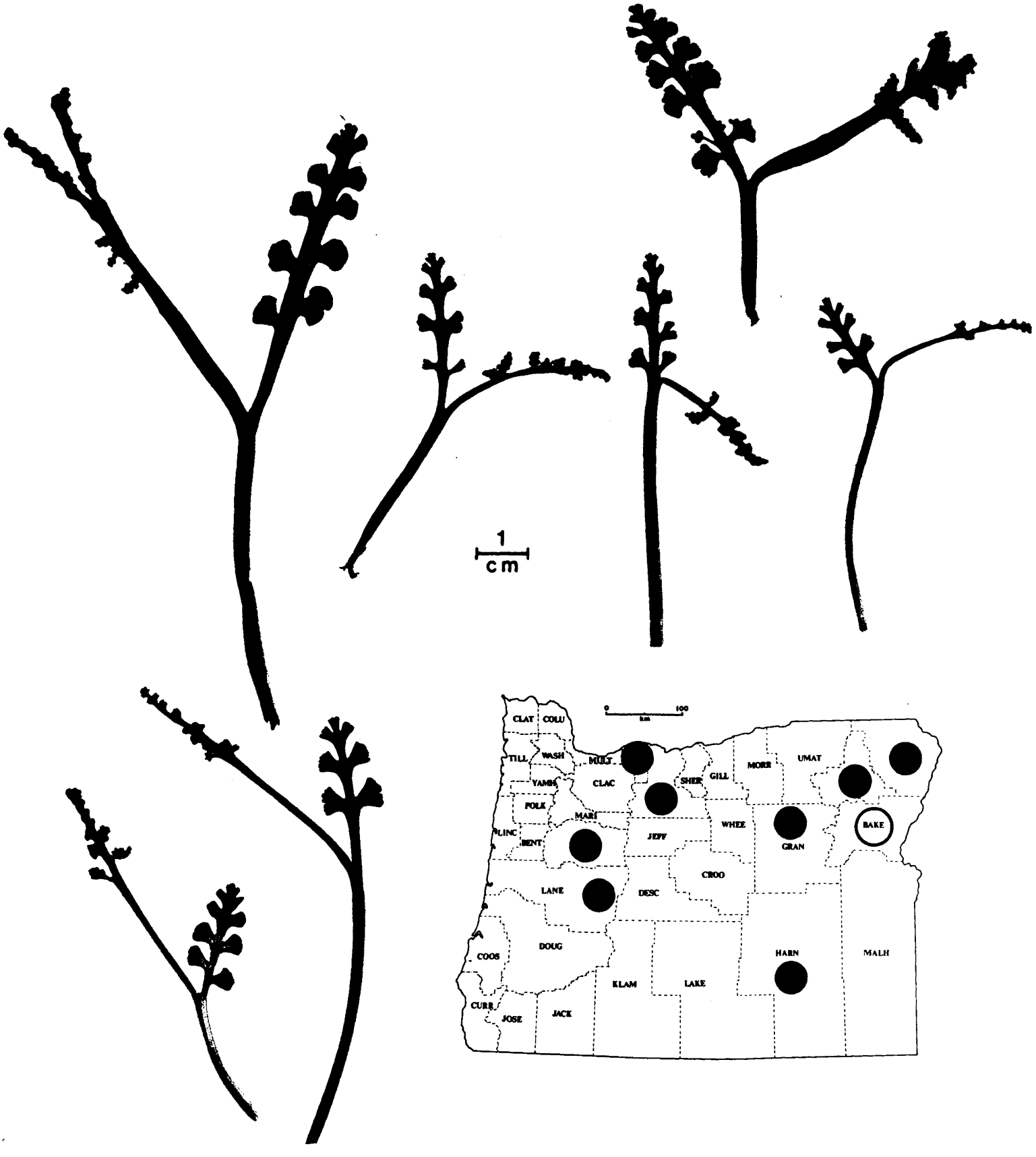
Figure 5. Botrychium minganense
map and illustration

Botrychium minganense



Torrey 1853, Perkins 1888, Brainerd et al. 1900, Eggleston et al. 1915, Dole 1937, Seymour 1969). Historical records were examined to establish possible causes for species changes.

Results. The study area supports 85 vascular plant taxa (Zika 1986); most are typical of contiguous boreal forest. Table 1 lists 21 rare native species restricted to open or alpine habitats. Since all were recorded in the 1800s, it would appear that no native alpine species immigrated this century.

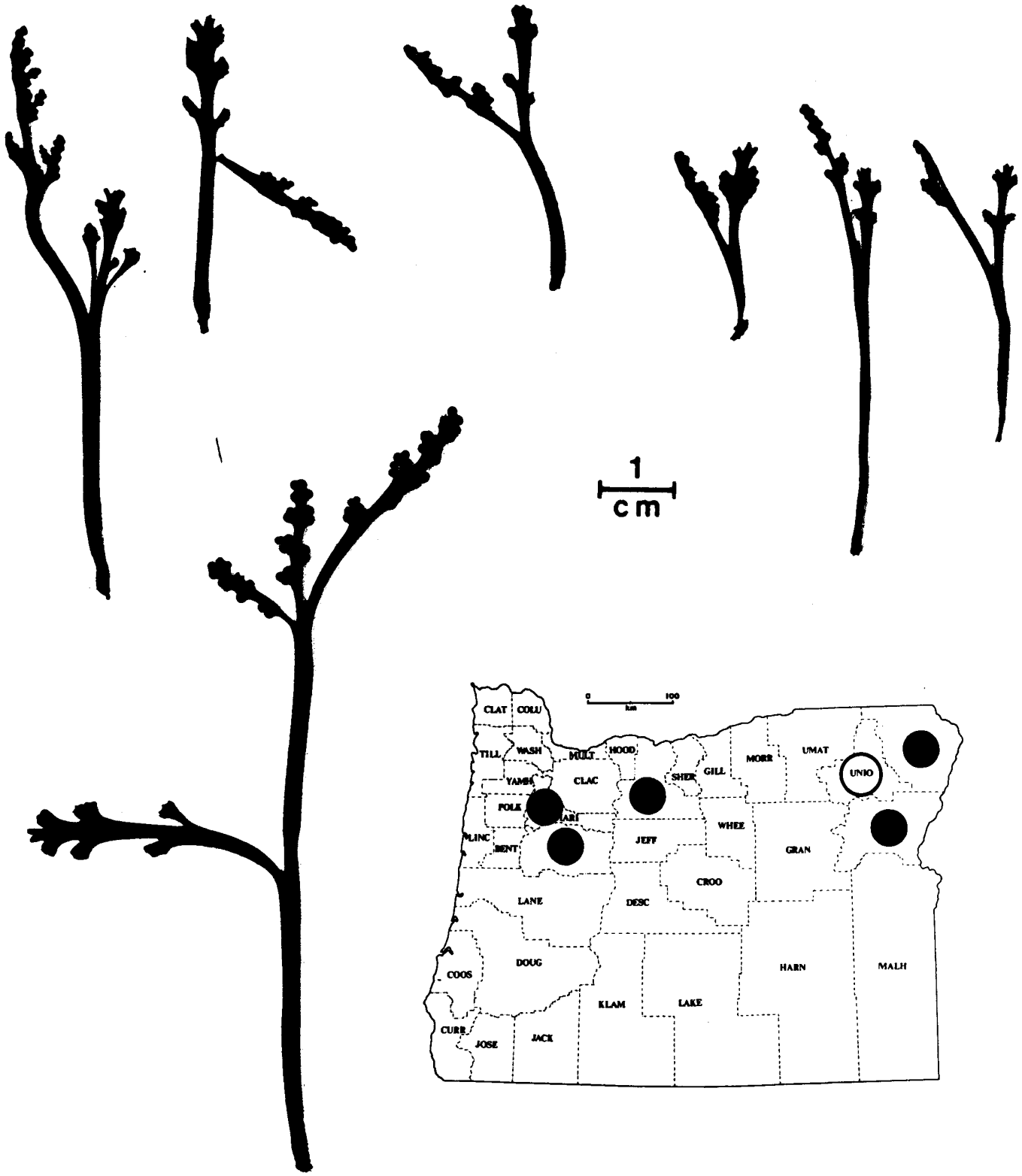
Four species known from the 1800s were not recorded this century: Alnus viridis (Villars) Lam. var. crispa (Michx.) House [mt. alder], Hierochloe alpina (Sw. ex Willd.) R. & S. [alpine sweetgrass], Polygonum viviparum L. [alpine bistort], and Vaccinium vitis-idaea L. [mt. cranberry]. To establish the period when they disappeared, a review of their documentation is needed.

Hierochloe alp irum collections from 1876 are extant at VT, and P ussed his P. viviparum record.

Documentation ccinium vitis-idaea between 1829 and 1839 is less di nt flora, Oakes stated he examined vouchers f luding alpine plants collected on Camels Hump by J. W. Macrae in 1839, and E. Tuckerman in 1839. My survey licated ca. 5-10% of the specimens Oakes saw der and mountain cranberry are among the missing co s' records, despite the absence of specimens, for several reasons. (1) Four botanists saw or collected the species. (2) Oakes' (1842) account is corroborated by a reference to mt. alder on Camels Hump in Tuckerman's unpublished journal on 28 July 1840 (Amherst College Archives). (3) The records are plausible. They are common, widespread members of the northeastern alpine flora. (4) A. viridis and V. vitis-idaea are easily recognized, so misidentification is unlikely.

Figure 6. Botrychium montanum
map and illustration
(slightly enlarged)

Botrychium montanum



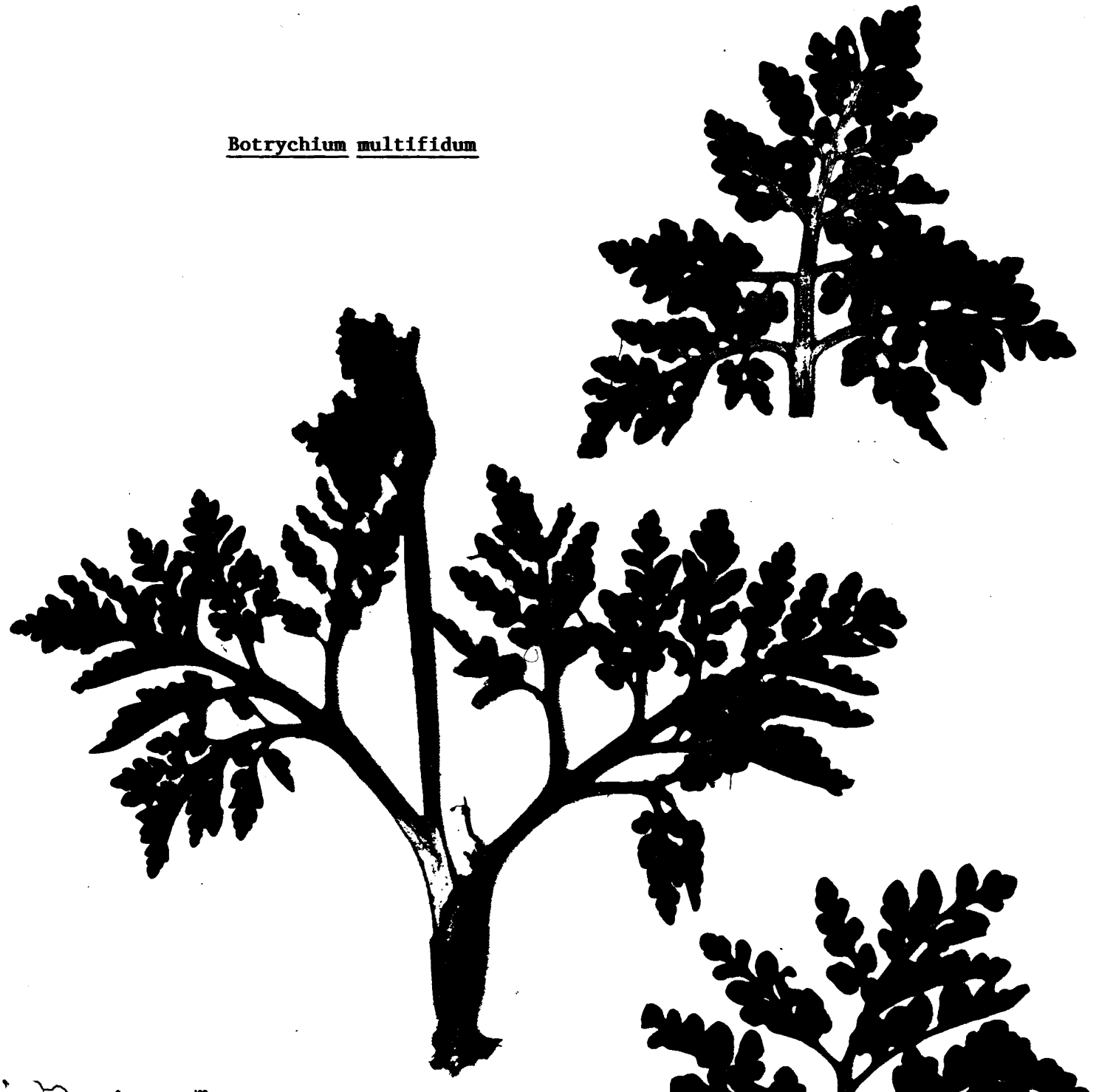
(Anonymous 1927); Torrey Botanical Club and American Fern Society in 1926 (Chisholm 1926); Kirk, 1930's (Dole 1937); McCauley in 1943; Cook in 1959-1960; Seymour, Charette, Siccama and others 1960+). Brainerd and others gathered both species elsewhere. These taxa are inconspicuous but not difficult to locate on other peaks. I conclude both probably disappeared from the study area by 1877.

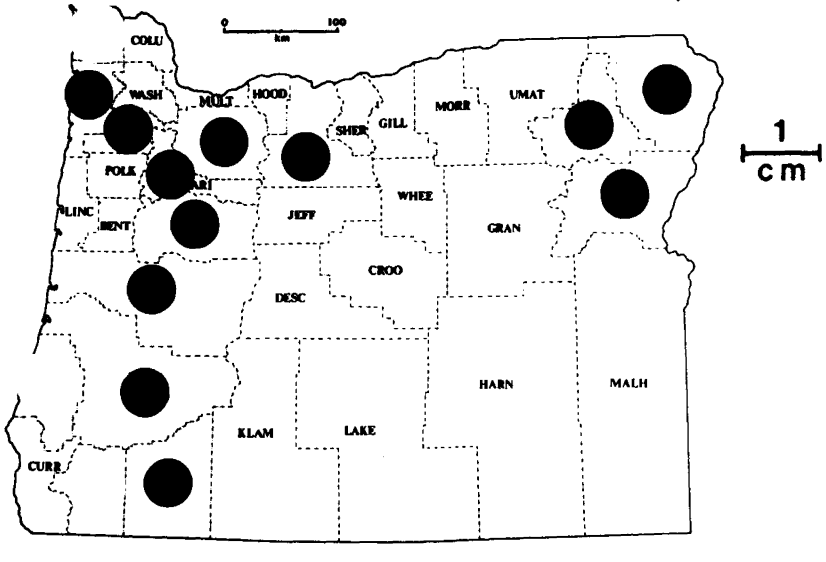
Pringle, who was selling specimens (Anonymous 1877a, 1877b; Davis 1936), may have overcollected the species in 1876. If P. viviparum and H. alpina populations were small and sensitive to disturbance, Pringle may have extirpated them. A modern collector described to me a similar situation on Mt. Mansfield, Vermont. He gathered specimens from the lone clump of H. alpina on the summit of the Nose of Mt. Mansfield around 1970. This may have fatally damaged the plant, albeit unintentionally. Careful searches by him, myself and others failed tc ı the following years (Zika, unpubl. data).

H. alpina and P. viviparum populations before they disappeared. Possible explanations, as n, include recreation-related trampling, develc ces, climatic warming, stochastic events and comt cs.

There is indirect evidence that drought contributed to the decline of Polygonum vivi ina. Both are restricted to the alpine zone in Ne ıt noted for its cold, moist growing conditions (Bliss 1973). Hot droughty weather has been implicated in the decline of some low elevation species restricted to cold or moist microsites. Examples include Picea rubens in New Hampshire (Hamburg and Cogbill 1988), Phyllitis scolopendrium var. americanum in New York (D. J. Leopold, pers. comm.), Aconitum noveboracense in New York (Dixon and Cook 1990, Dixon and May 1990), and Anemone multifida in Vermont (J. C. Jenkins, pers. comm).

Botrychium multifidum





1
cm

Figure 7. Botrychium multifidum map and illustration

Fig 7
multifidum

1
cm

Figure 8. Botrychium paradoxum map and illustration

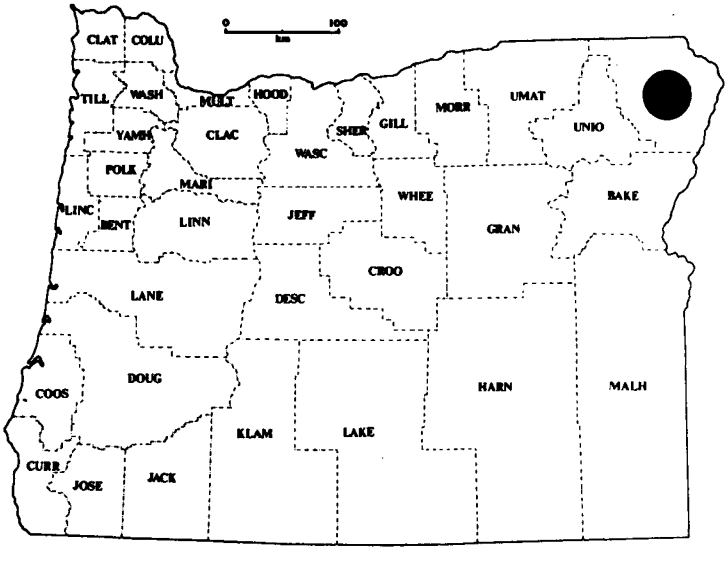


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Figure 9. Botrychium pedunculosum map and illustration

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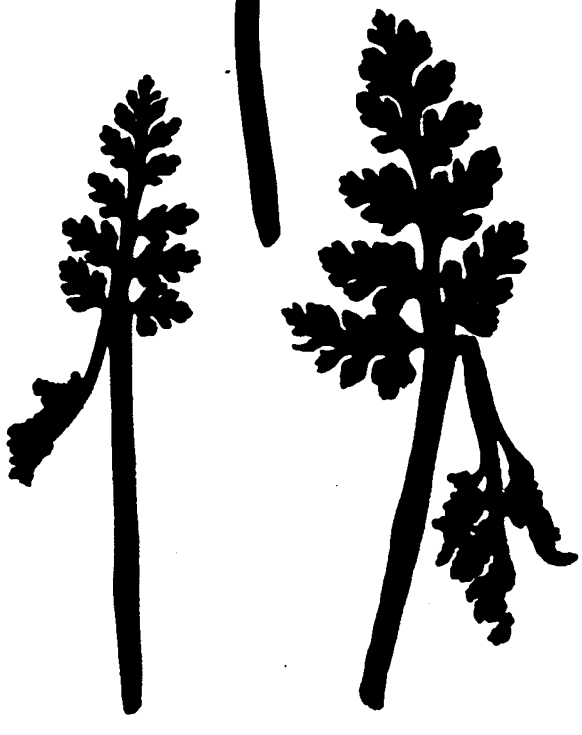
Figure 10. Botrychium pinnatum
map and illustration



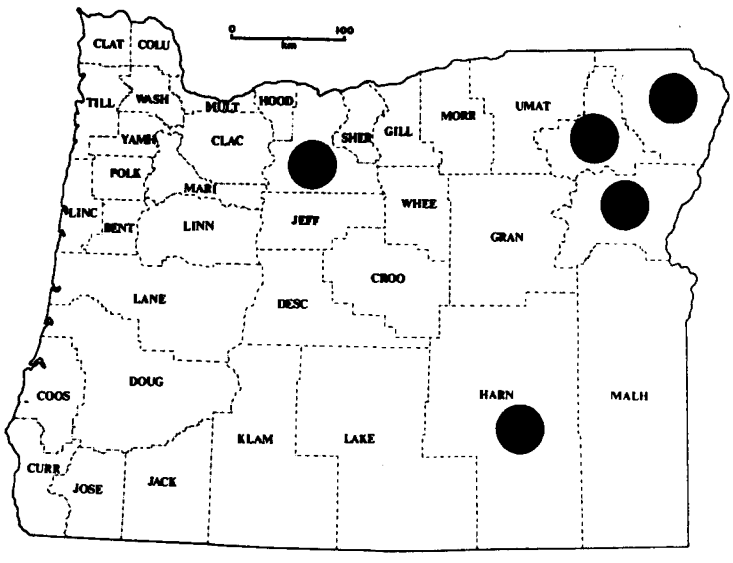


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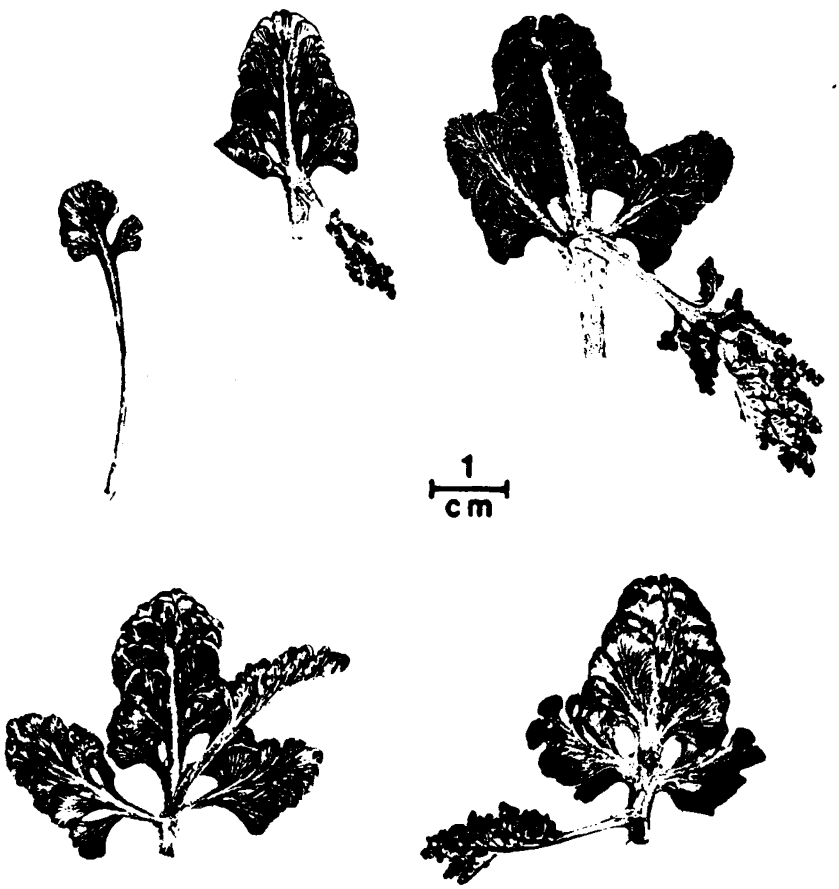
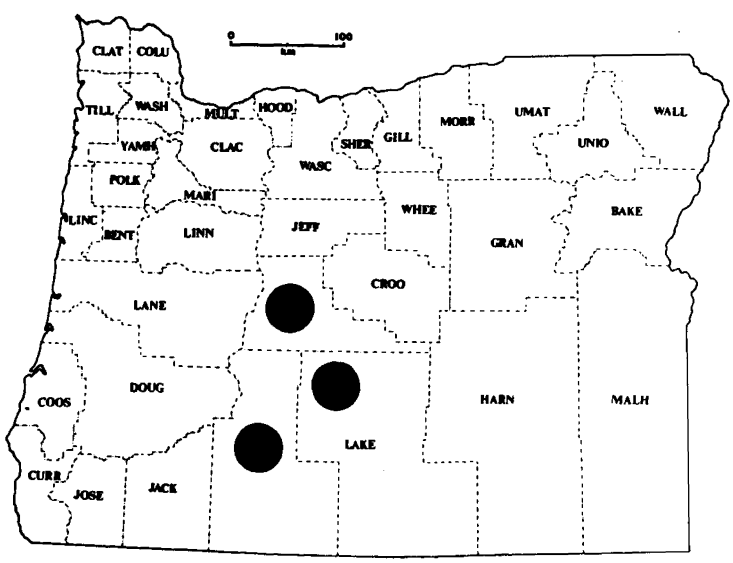
Figure 11. Botrychium pumicola
map and illustration

Botrychium pumicola





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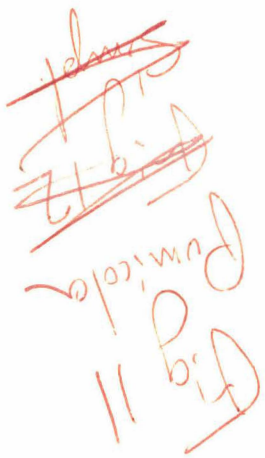
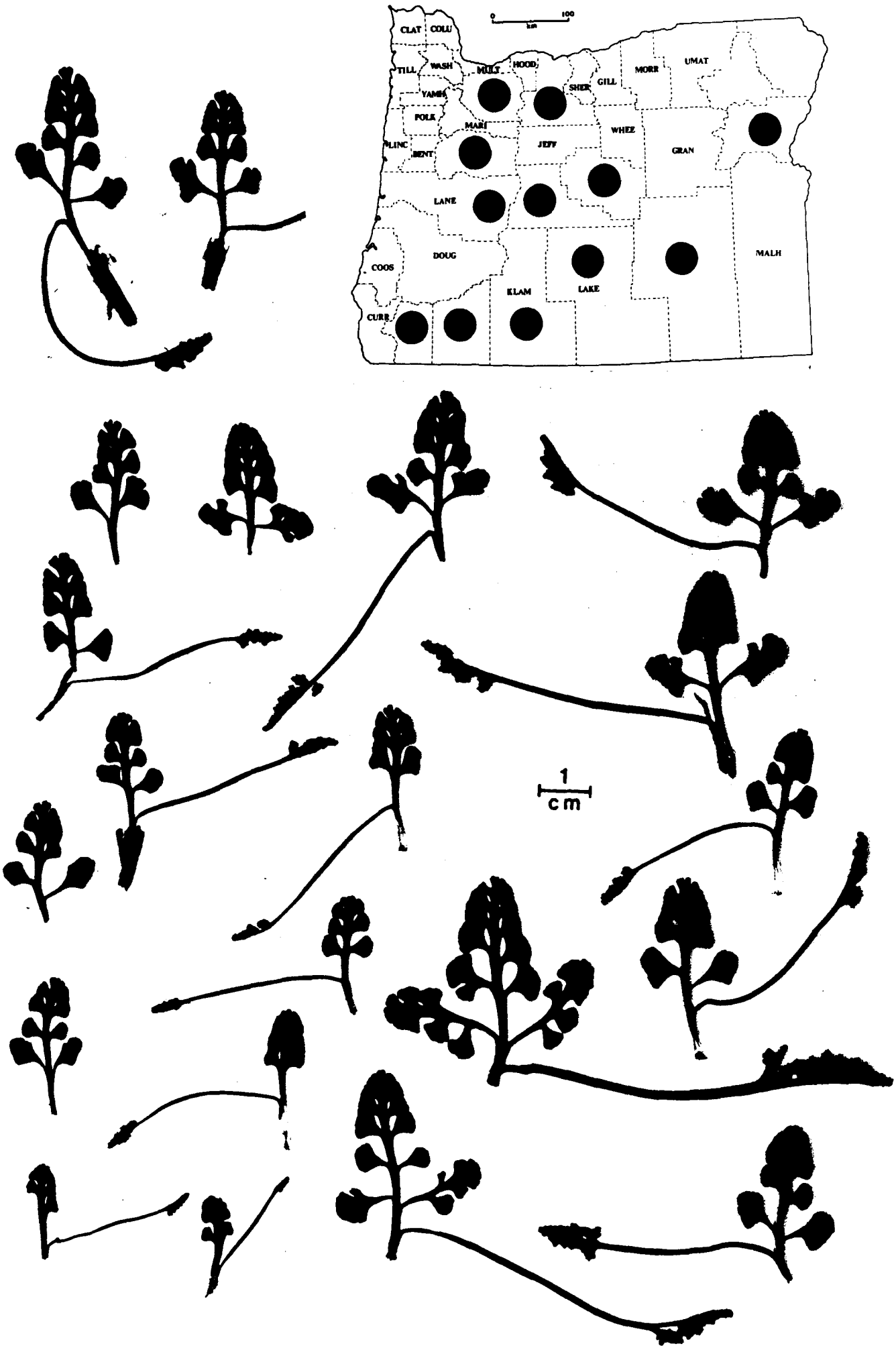


Figure 12. Botrychium simplex
map and illustration



Botrychium simplex

Figure 13. Botrychium virginianum
map and illustration

Botrychium virginiana

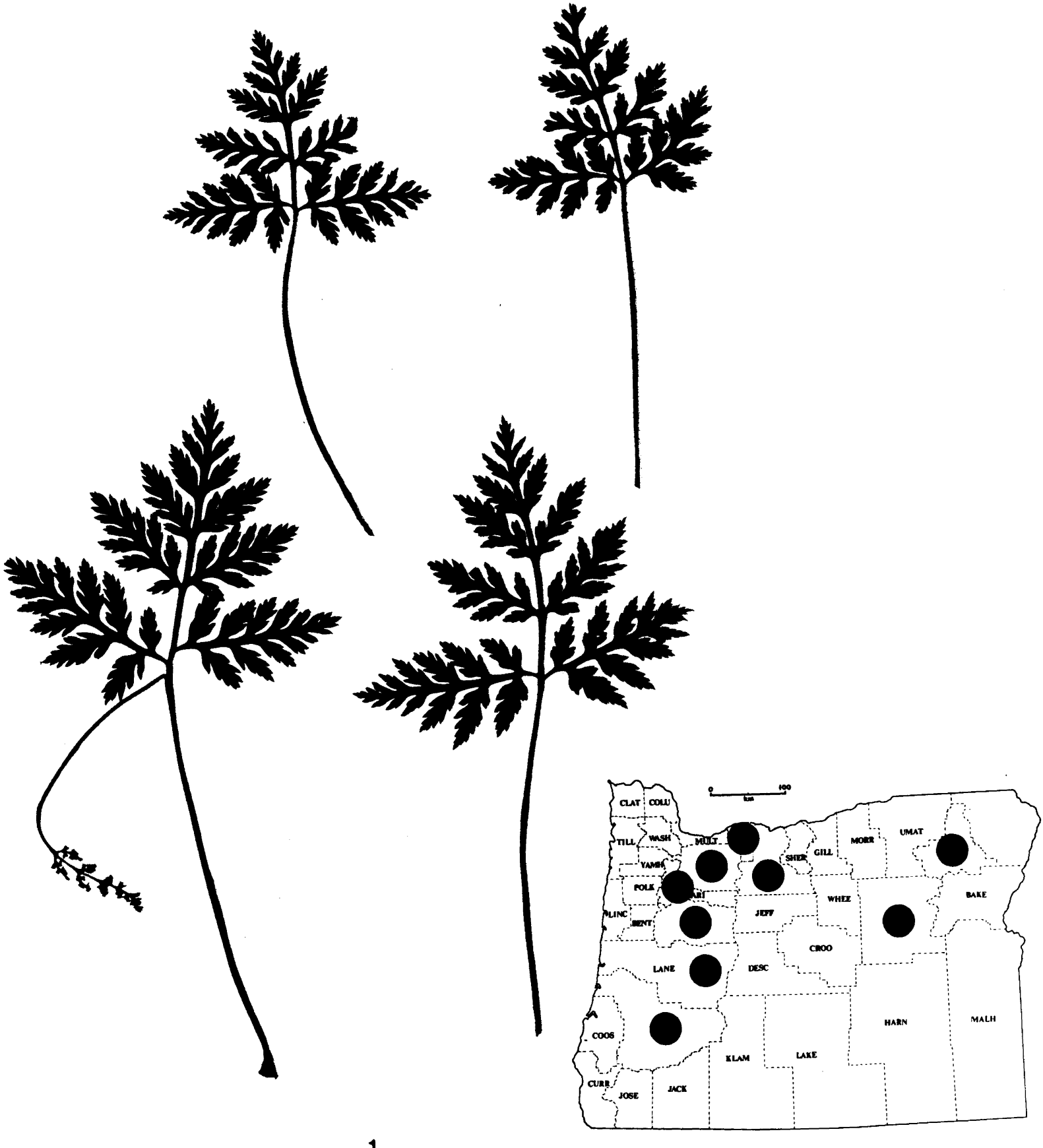


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Fig 13

Figure 14. Botrychium species "A" map and illustration

Botrychium species A

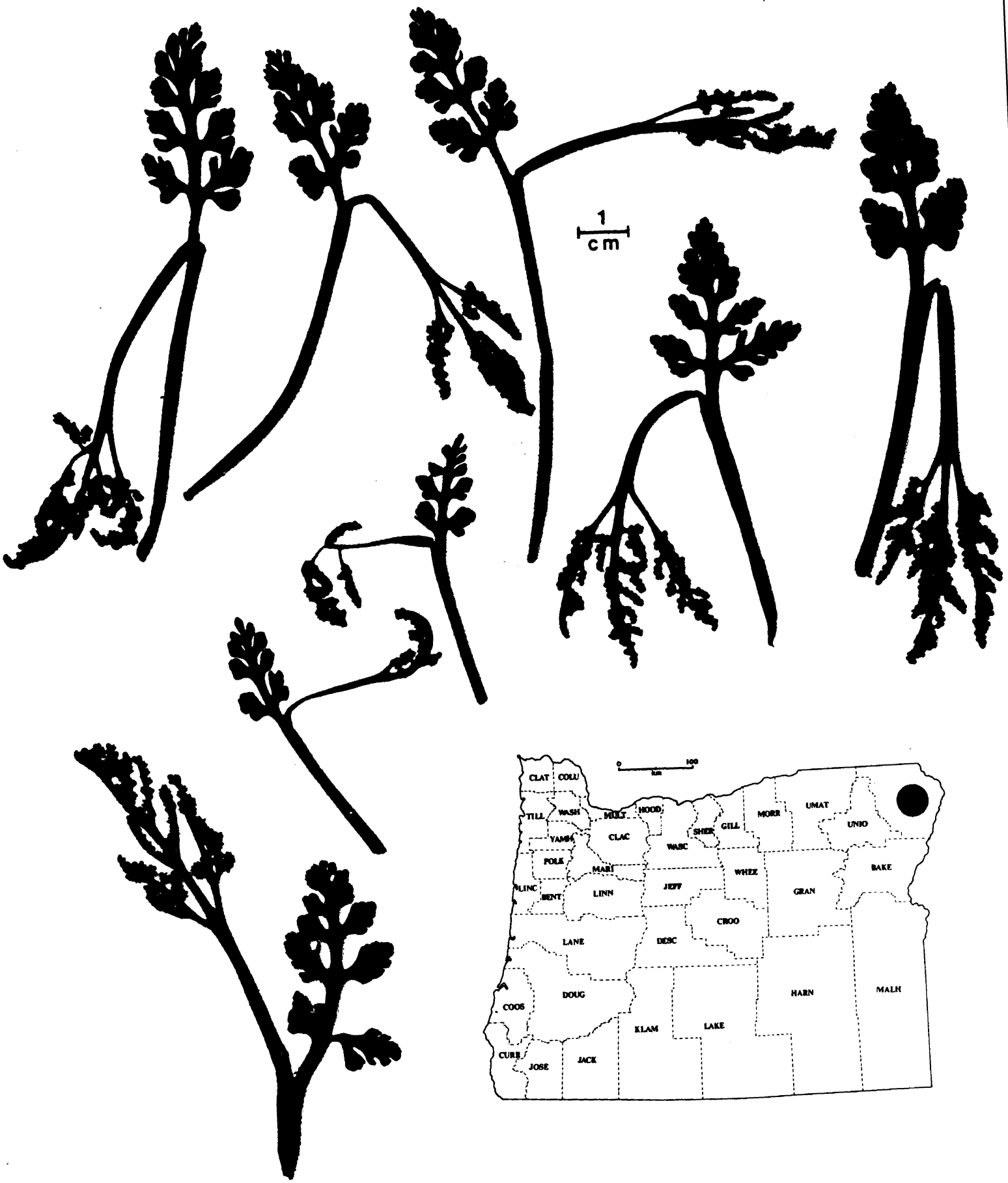

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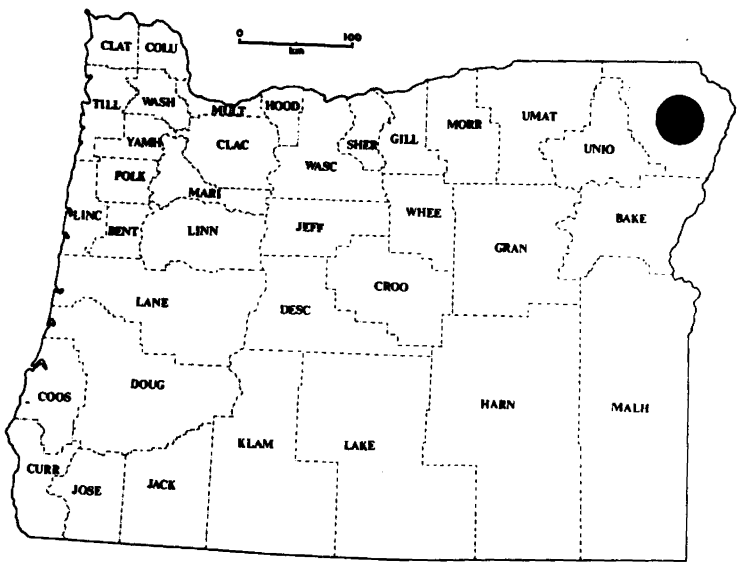
Figure 15. Botrychium species "B" map and illustration

Botrychium species B



southern precipice and peered into every fissure amongst the rocks."

Apparently V. vitis-idaea and A. viridis disappeared prior to 1874. Why? If restricted to small areas on the summit, they were vulnerable to development or habitat changes. Tree-cutting and construction began in the study area in 1845, resulting in an ever-increasing human impact. In 1859 a hotel was built at 1160 m (Waterman and Waterman 1989). A small observatory, built at 1244 m in the 1860's, decayed by 1877, when the hotel burned (Whitney 1988; Paris 1864; Woodward and Chase n.d.). The most likely explanation for the extirp[illegible] of mt. cranberry and mt. alder is soil compaction and trampling [illegible]971), resulting from hiking, camping, firewood [illegible] trails and structures. Alternative possibilities

Pack animals introdu[illegible]path after 1859 (Waterman and Waterman 1989) may ha[illegible] colonies of V. vitis-idaea and A. viridis (Price 19[illegible]; may have reduced V. vitis-idaea; browsing may have [illegible] small trampled and weakened colony may have succumbe[illegible]d 1855 (Whitney 1988).

Neither Alnus viridis nor [illegible]idaea were likely to be affected by the general climatic amelioration after circa 1850 (Dansgaard et al. 1975). Both species are known to persist at warmer, drier low altitude habitats across New England. What about weeds? Currently competition from exotic grasses (e.g., Poa pratensis, P. compressa, Agrostis capillaris) is severe (in disturbed habitats) on Camels Hump and Mt. Mansfield, threatening non-rhizomatous native graminoids. Yet Vaccinium vitis-idaea persists in weedy areas on the Nose of Mt. Mansfield; it appears to be weed tolerant.

THE LOSS OF POLYGONUM VIVIPARUM AND HIEROCHLOE ALPINA. Both are completely absent in the collecting record after Pringle's 1876 visit (Brainerd in 1877 (Brainerd et al. 1900); W. H. Blanchard in 1912-1918; Ross in 1923; Carpenter, Rugg, Dole and the Vermont Botanical Club in 1926

Botrychium matricariifolium

sax:0a 9 Nov 90 12 Nov 91

Running head:

ZIKA AND JENKINS: ADIRONDACK FLORA

Address for mailing proof:

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Cornelius, OR 97330

Con **of the Adirondacks, New York.**[1]

F. Zika

ge Program, 1205 NW 25th

, OR 97210

C. Jenkins[2]

White Creek, NY 12057

ABSTRACT

Zika, P. F. (Oregon Natural Heritage Program, 1205 NW 25th, Portland, OR 97210) AND J. C. Jenkins (White Creek, NY 12057). Contributions to the flora of the Adirondacks, New York. BULL. TORREY BOT. CLUB XX:000-000. 19XX.-Surveys of wetlands, cliffs and alpine areas in the Adirondacks region of northeastern New York resulted in 12 new stations for rare native species. Saxifraga oppositifolia is an addition to the New York flora. Additional stations are recorded for two recently reported species in New York: Empetrum eamesii ssp. atropurpureum and Trisetum melicoides. Erigeron

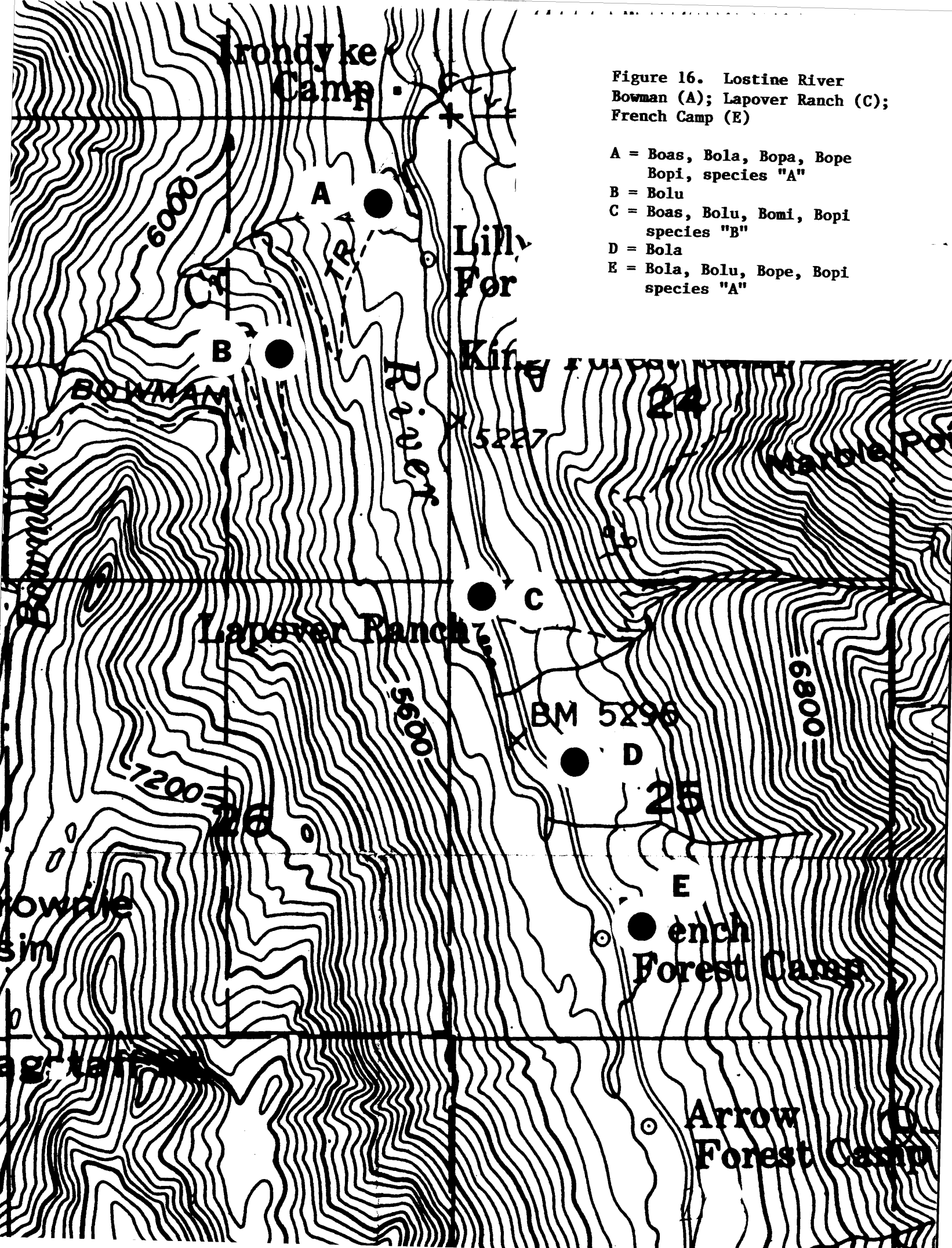


Figure 16. Lostine River
Bowman (A); Lapover Ranch (C);
French Camp (E)

A = Boas, Bola, Bopa, Bope
Bopi, species "A"
B = Bolu
C = Boas, Bolu, Bomi, Bopi
species "B"
D = Bola
E = Bola, Bolu, Bope, Bopi
species "A"

Fig 16

A = as Bilia

B = historical site for lu

C = as. lu mi .

D =

E = la, lu

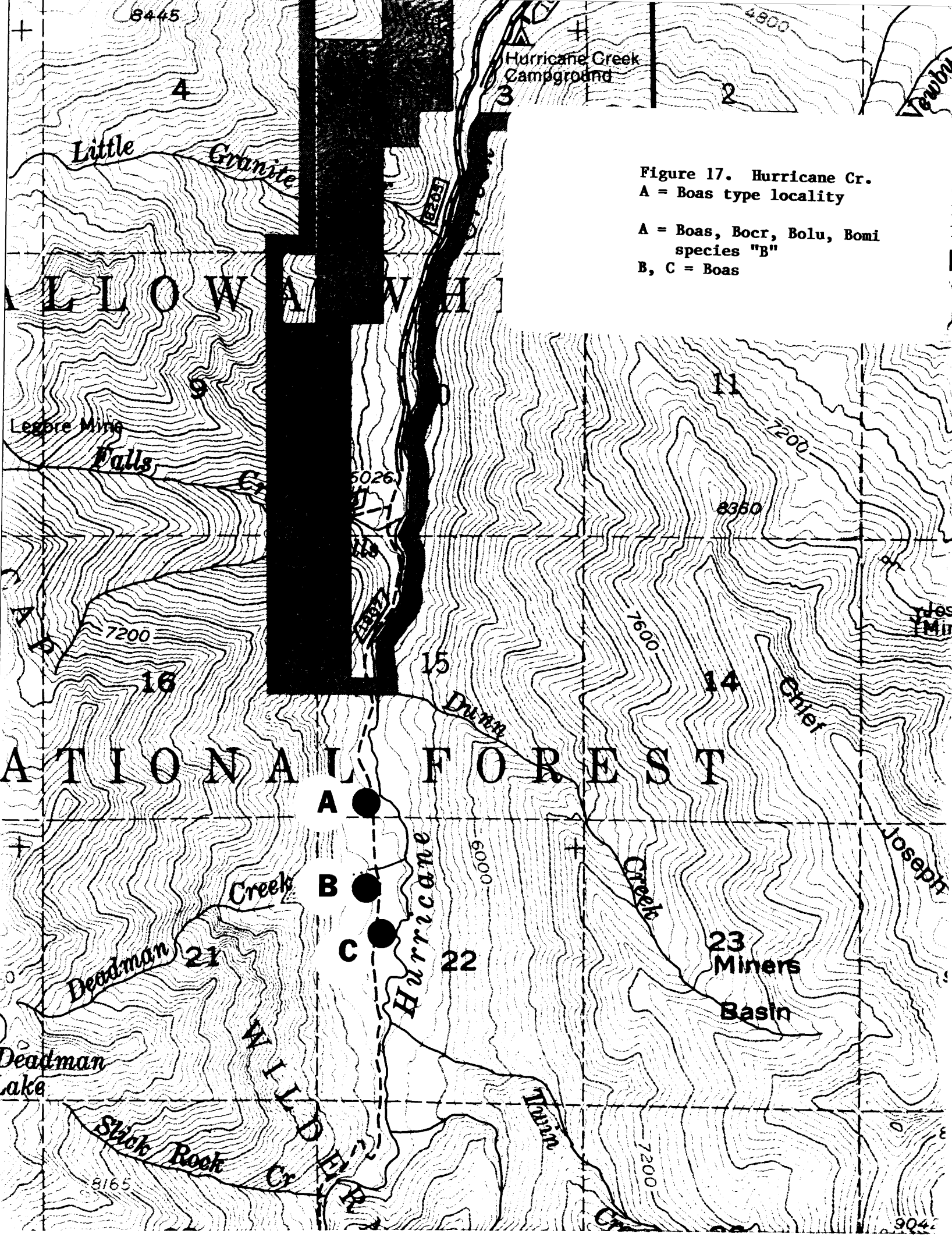


Figure 17. Hurricane Cr.
A = Boas type locality

A = Boas, Bocr, Bolu, Bomi
species "B"
B, C = Boas

Figure ~~XX~~ 17

Botrychium on lower Hurricane Creek.

A = B. ascendens type locality
B. crenulatum
B. lunaria
B. iminganense
B. "species B"

Be = B. asc.

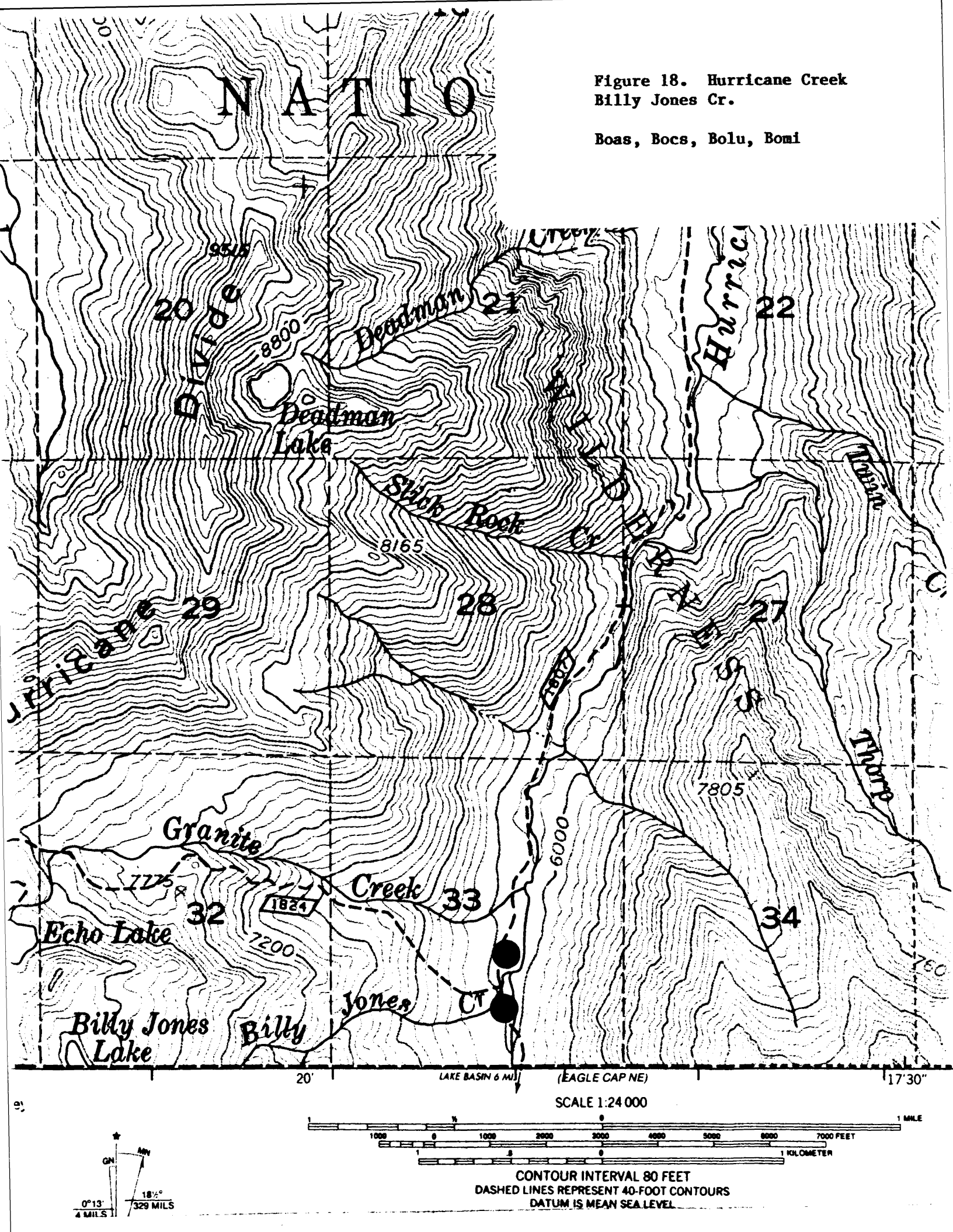


Figure 18. Hurricane Creek
Billy Jones Cr.

Boas, Bocs, Bolu, Bomi

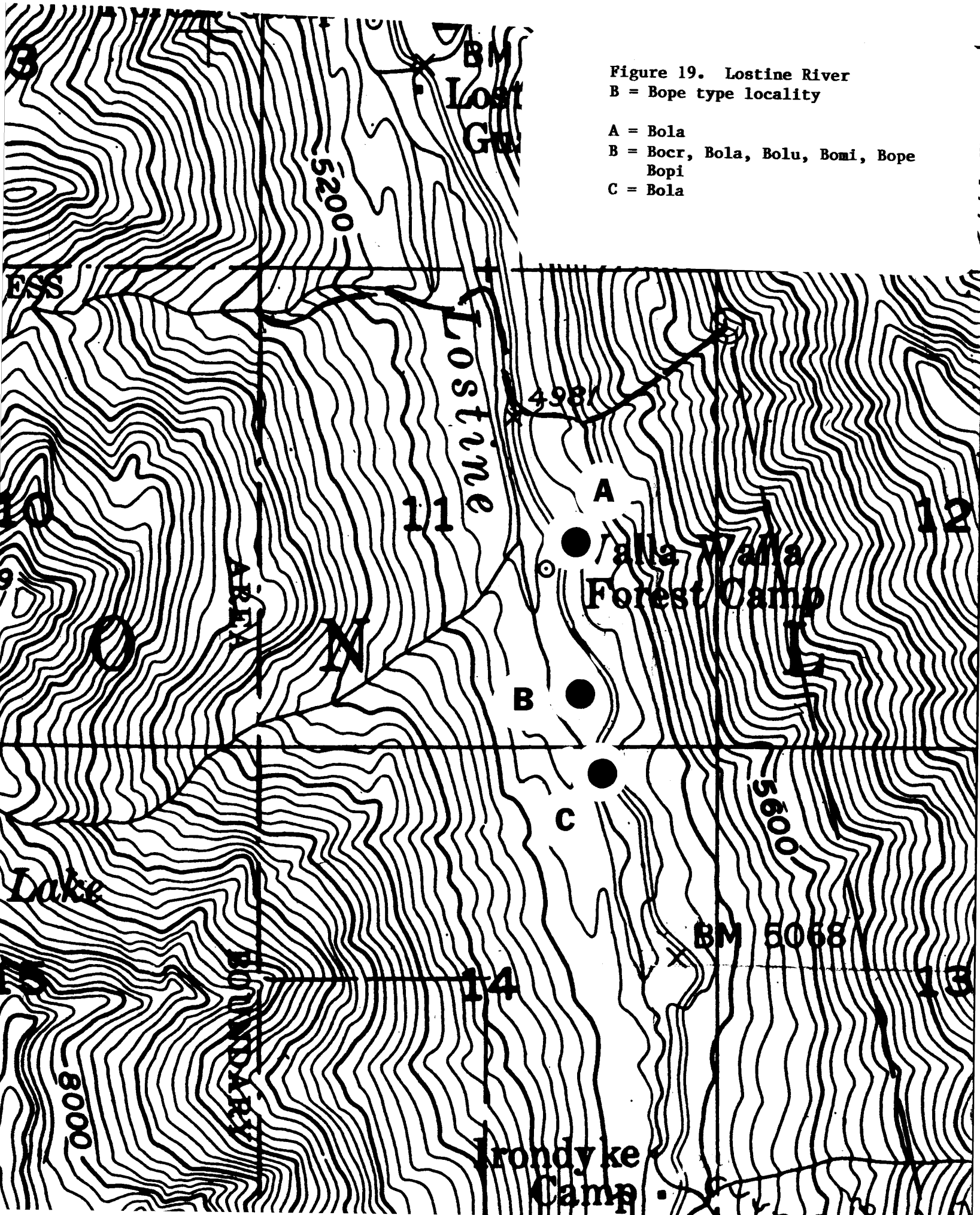


Figure 19. Lostine River
B = Bope type locality

A = Bola
B = Bocr, Bola, Bolu, Bomi, Bope
Bopi
C = Bola

Fig 19

A=

B= Bo cr, la, ka, mi
ped (type loc.)

C = la.

Figure 20. Lostine River, Two Pan vicinity

A = Bola, Bomi, Bopi, unidentified spp.
B = Bola, Bolu, Bomi, Bopi
C = Bola, Bopi
D = Bomi, Bopi

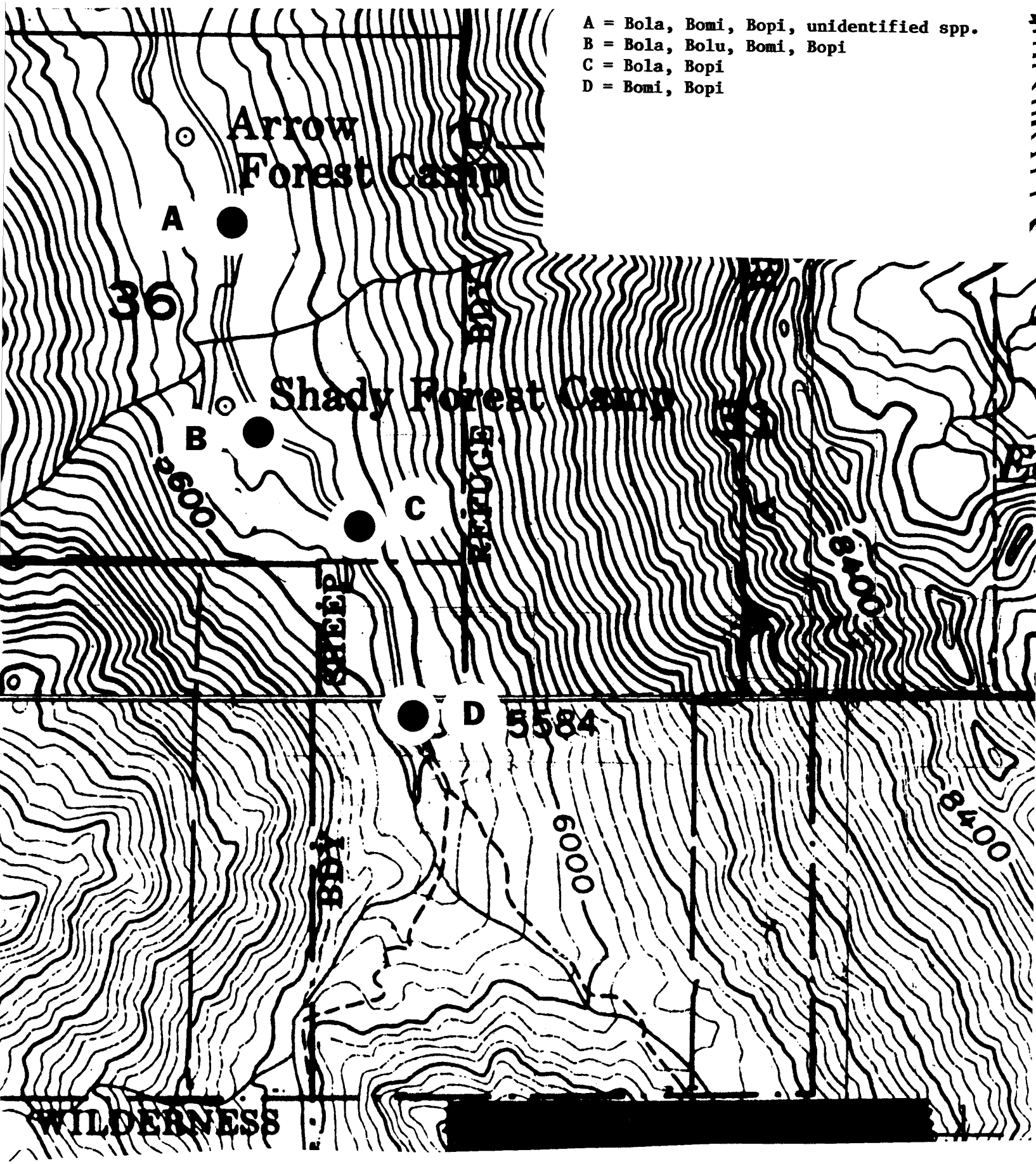


Fig 20 **

A = lanc, ming, pinn
?pad, ?sp A

B = lanc, lun, ming, pin

C = lanc, pin

D = ming, pin

Figure 21. W. Fk. Wallowa River
Ice Lake

Bola, 2nd unidentified sp.

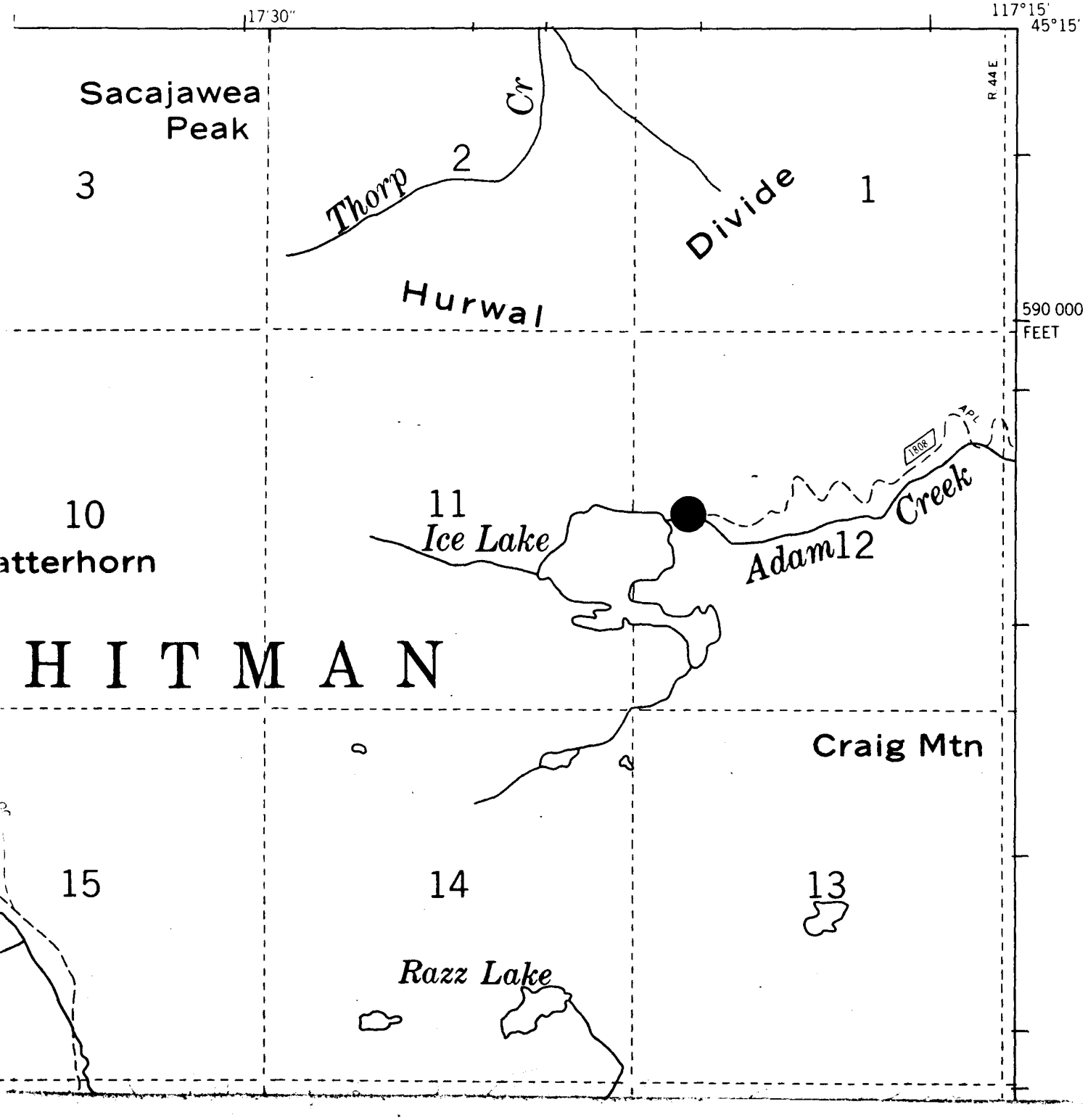
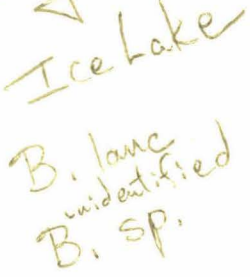


Fig 21 **



B. lanc
unidentified
B. sp.

Fig 22

B. lanc

B. pin

Approx loc.

Exact loc. uncertain

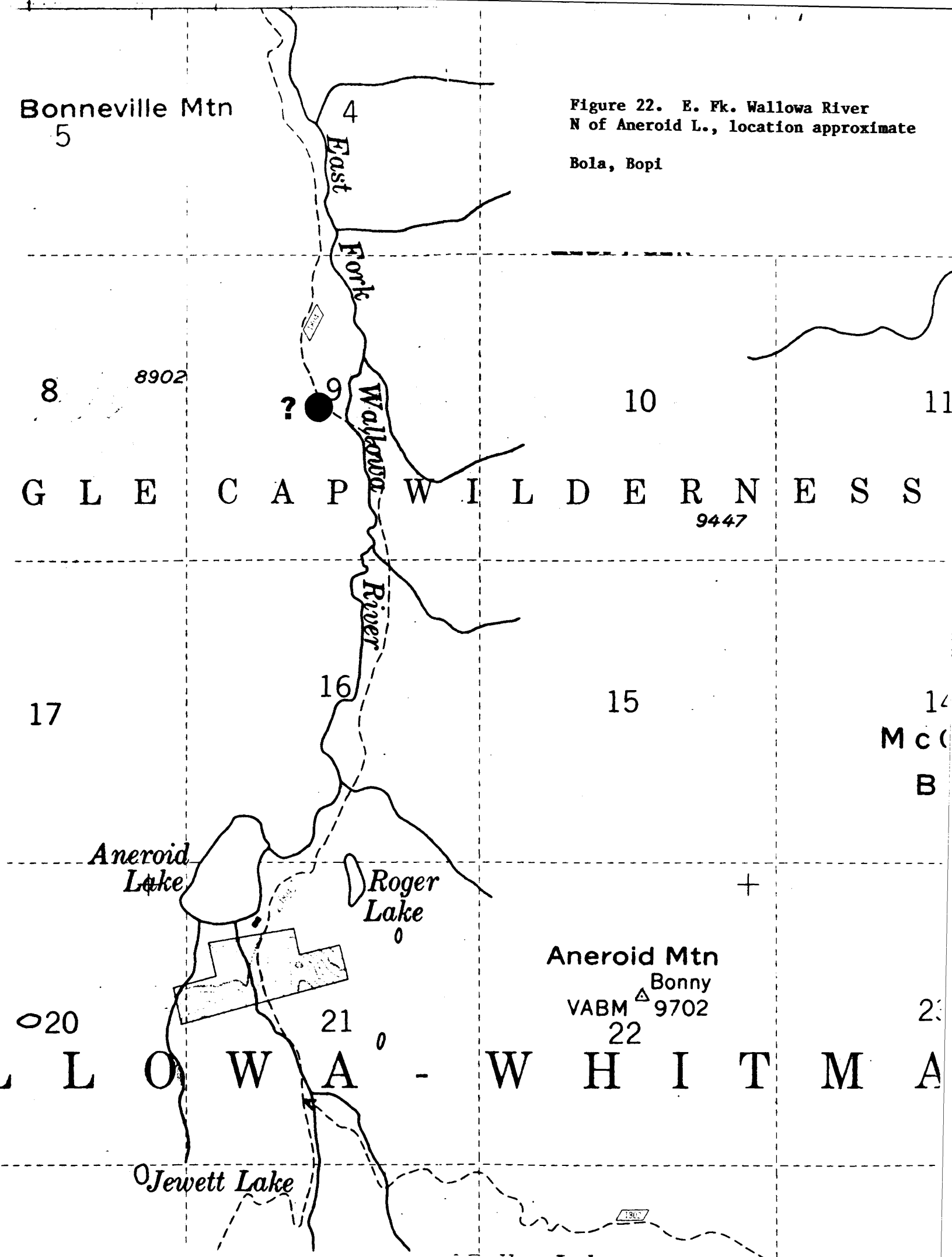


Figure 22. E. Fk. Wallowa River
N of Aneroid L., location approximate

Bola, Bopi

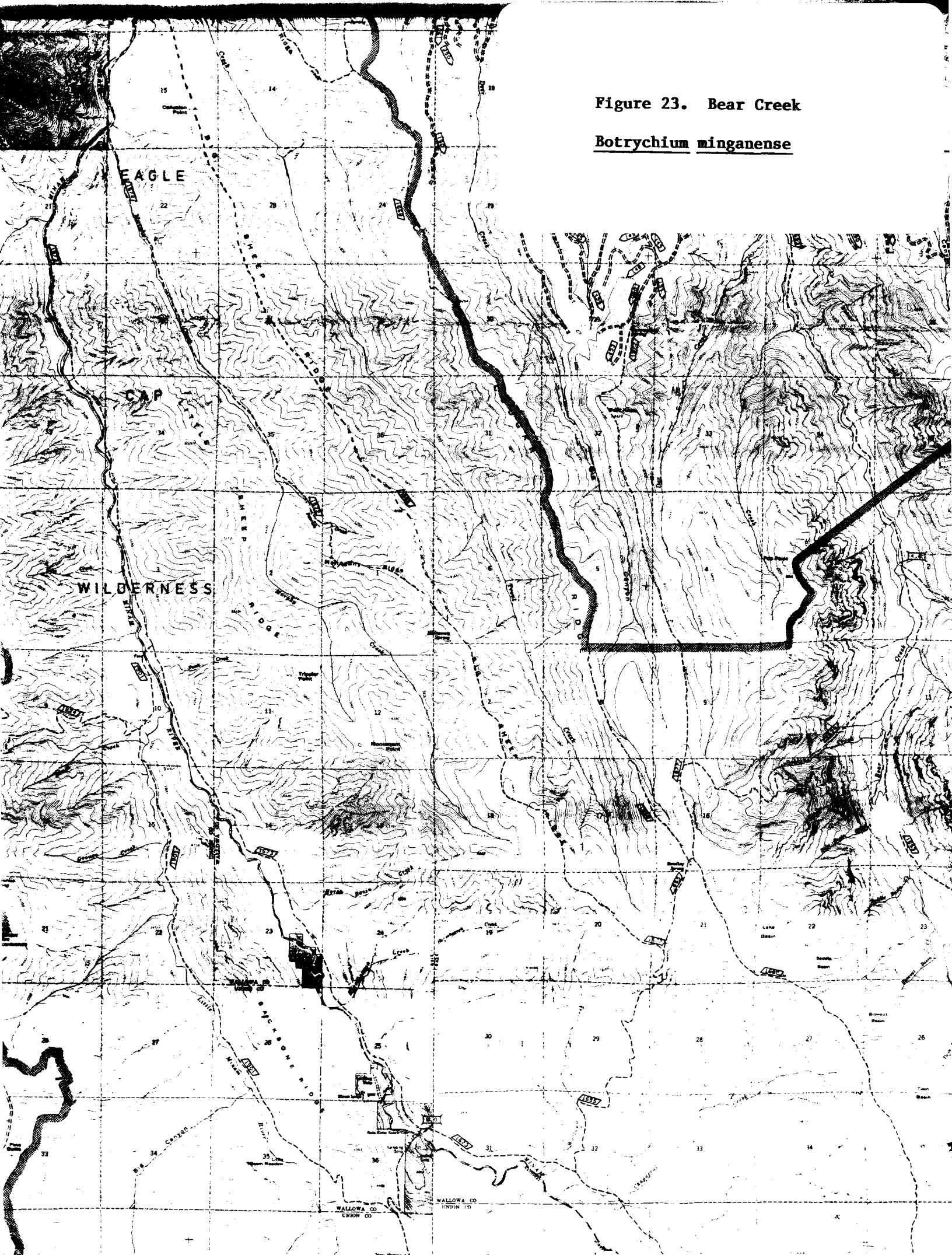


Figure 23. Bear Creek

Botrychium minganense

Fig 23 ~~XX~~

Bo ~~ming~~

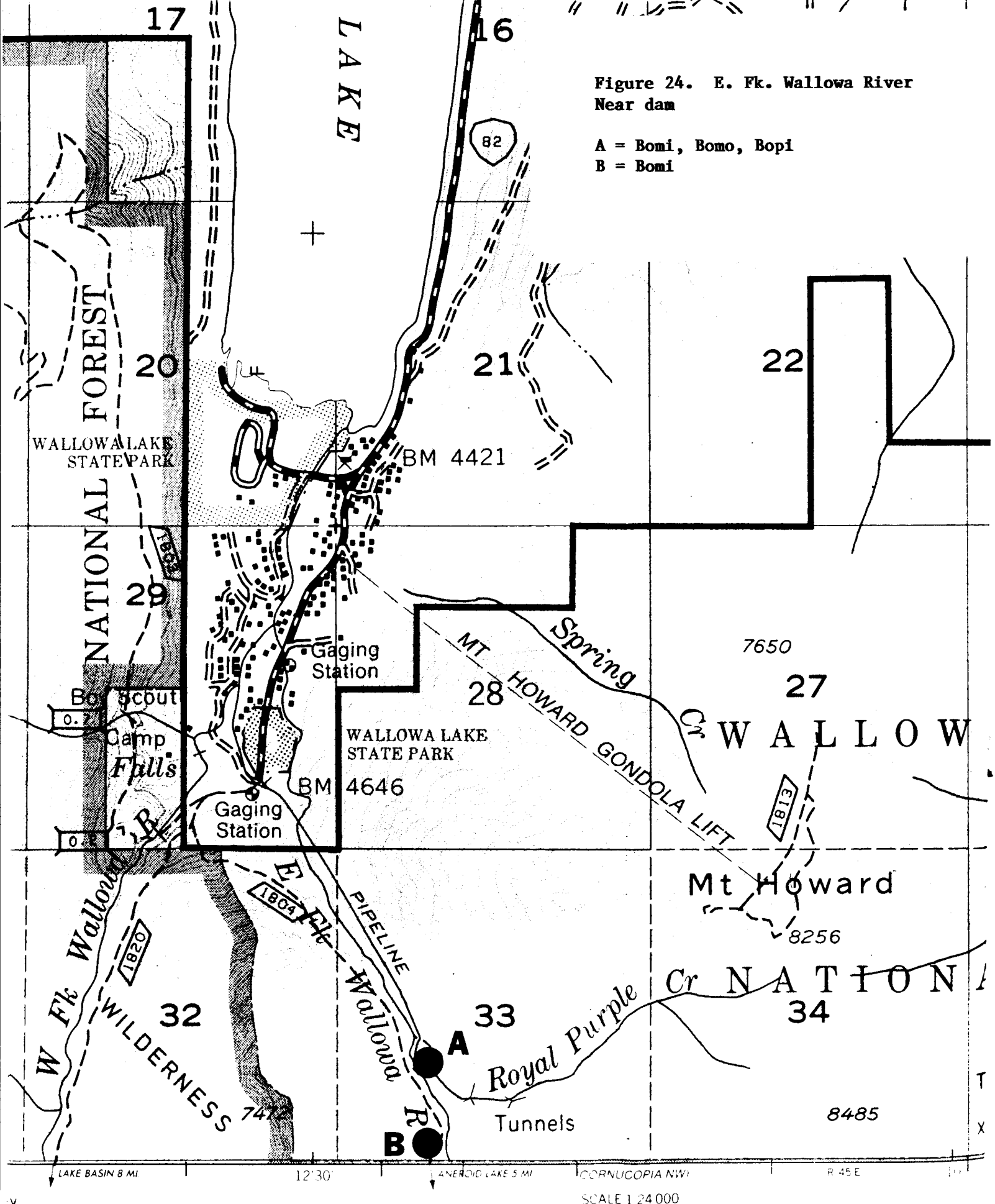


Figure 24. E. Fk. Wallowa River Near dam

A = Bomi, Bomo, Bopi
B = Bomi

Figure 24 ~~XX~~

Bo ming (A & B)

Bo mout (A)

Bo pin (A)

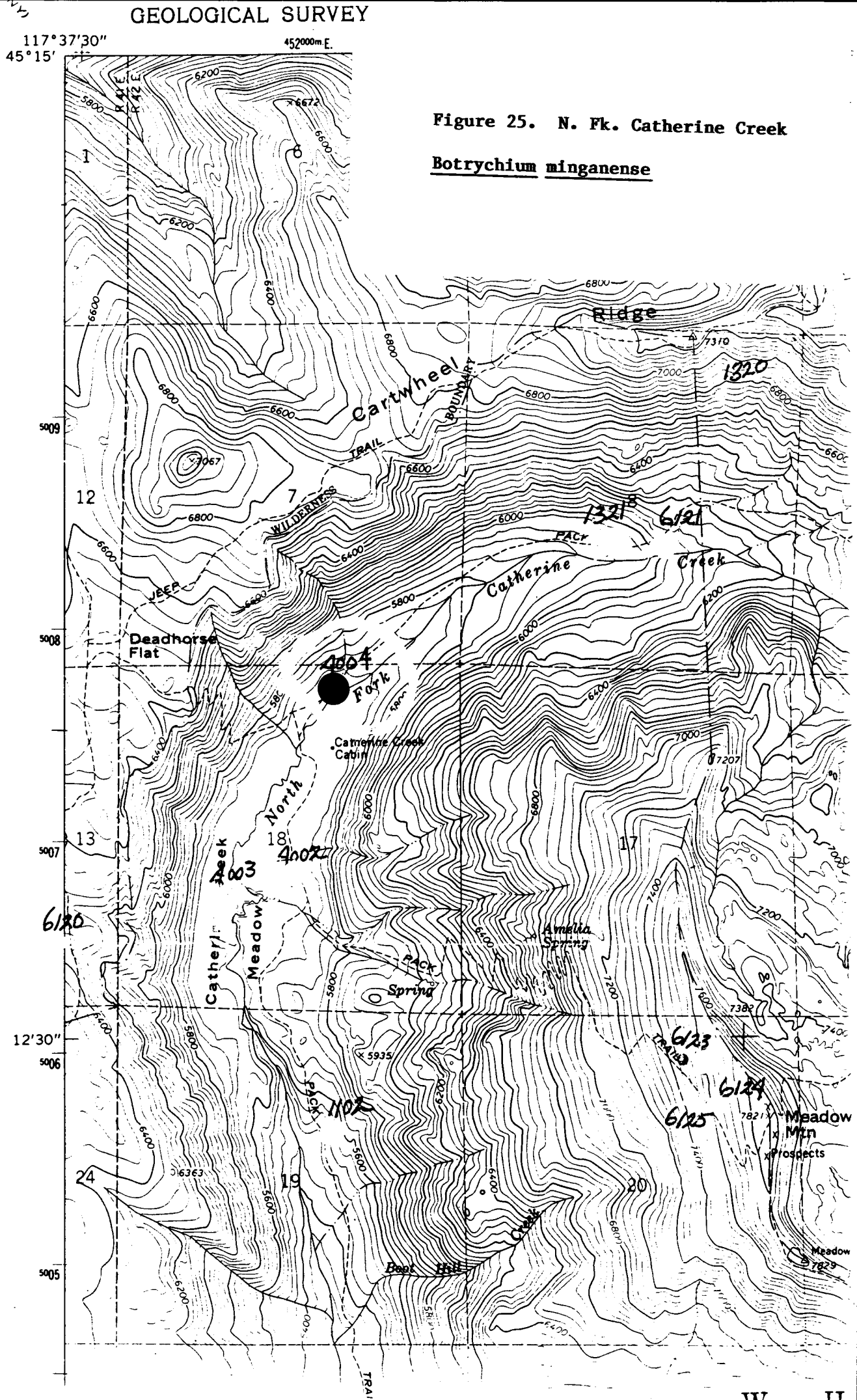


Figure 25. N. Fk. Catherine Creek

Botrychium minganense

1

CC for report

Bo ming

25

Fig ~~XX~~

Ming

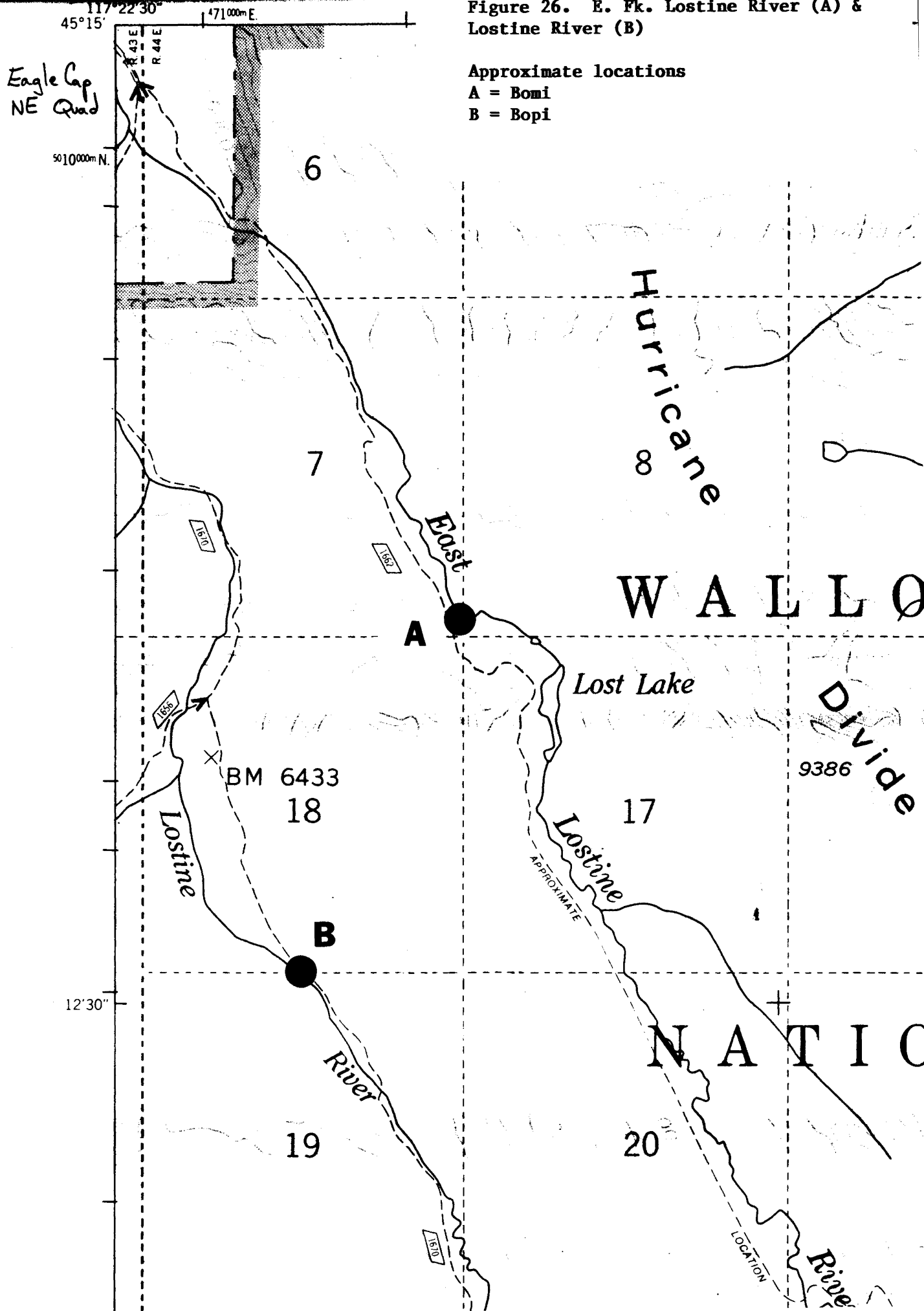


Figure 26. E. Fk. Lostine River (A) & Lostine River (B)

Approximate locations
A = Bomi
B = Bopi

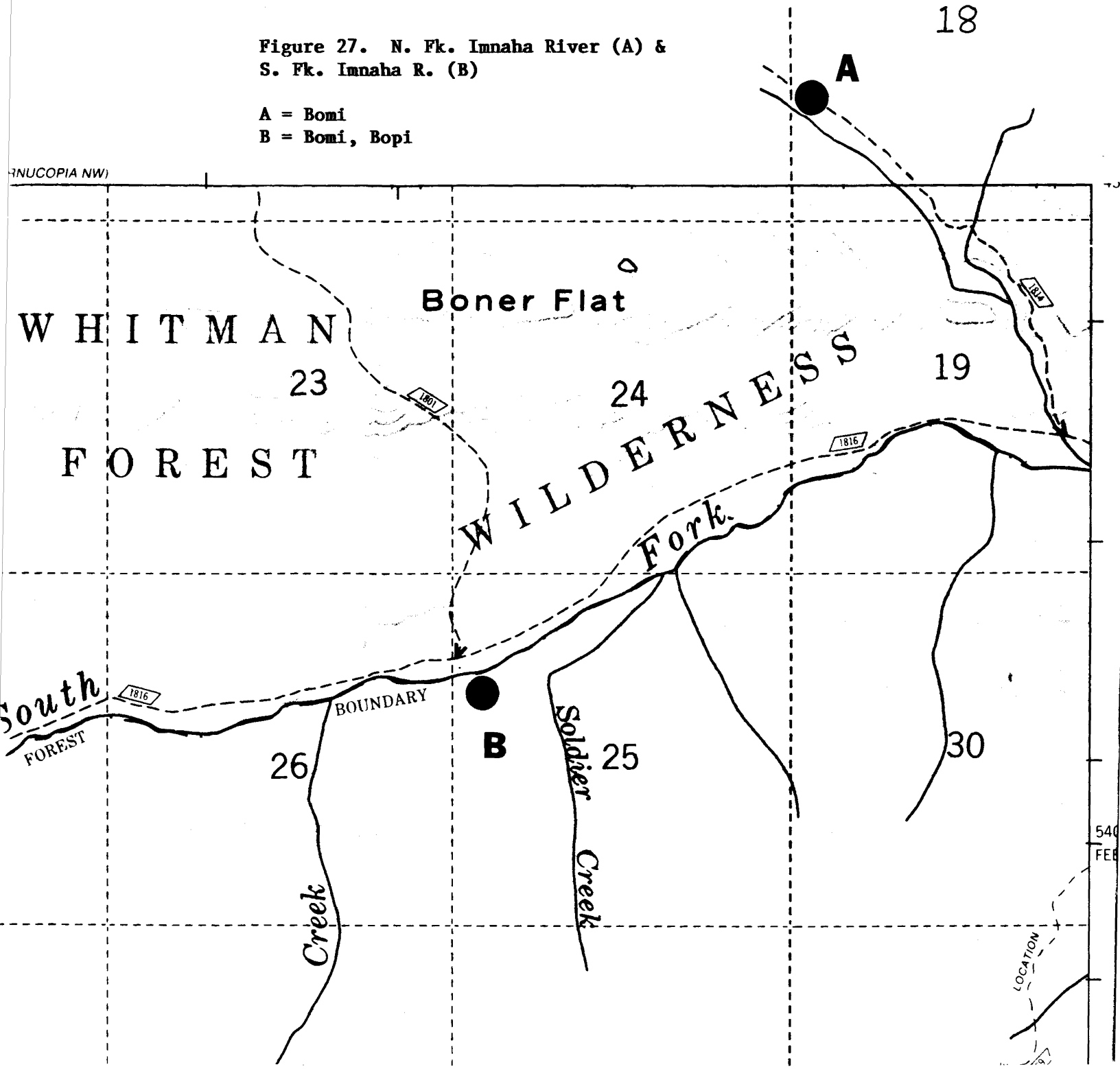
Fig 26 (
Approx loc. of
Historical cells

A = ming

B = pin

Figure 27. N. Fk. Imnaha River (A) & S. Fk. Imnaha R. (B)

A = Bomi
B = Bomi, Bopi



~~[illegible]~~

27

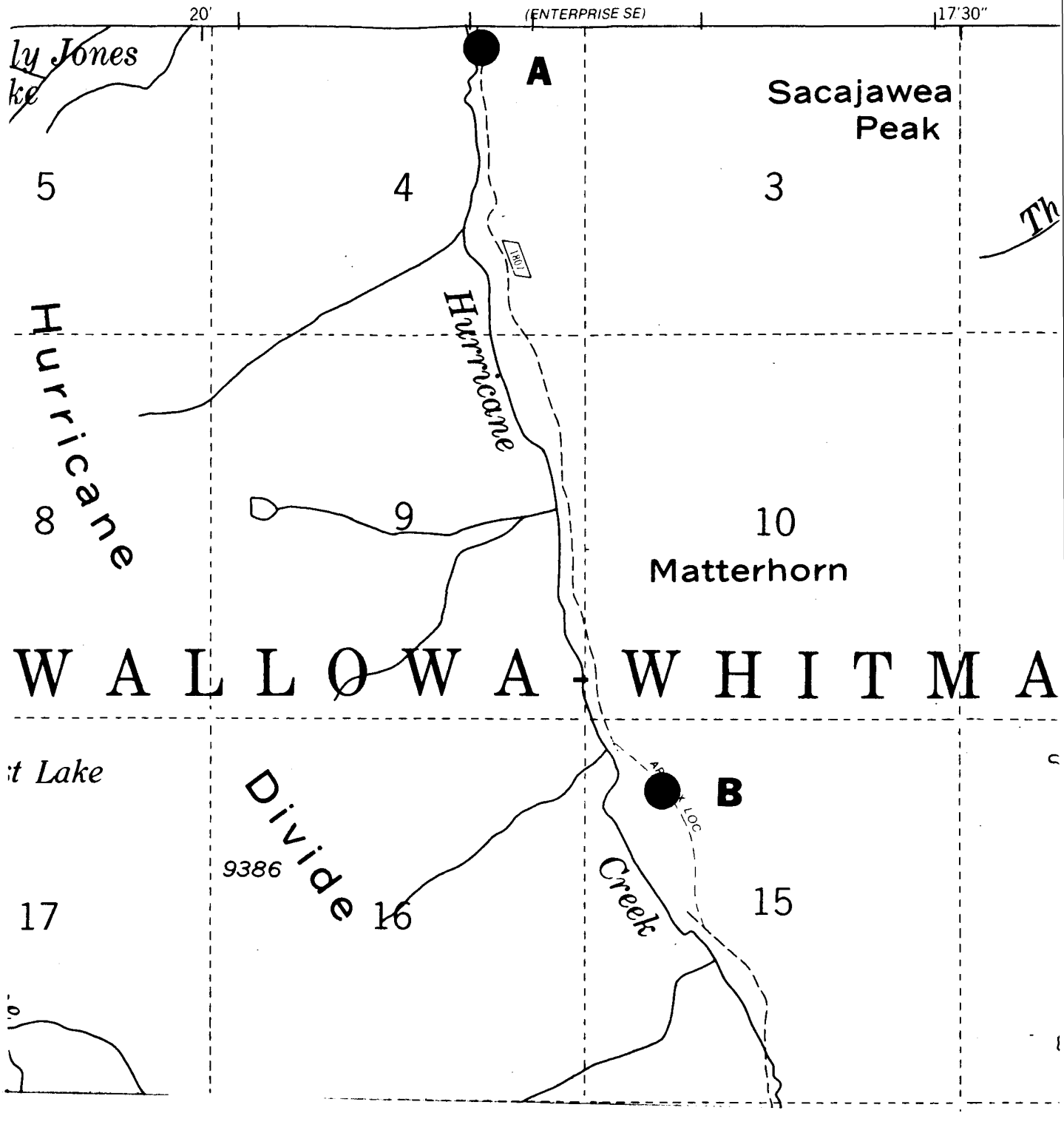
Fix ~~XX~~

A = ming

B = ming + pinn

Figure 28. Hurricane Creek, S of Billy Jones Creek

A, B = Unidentified Botrychium



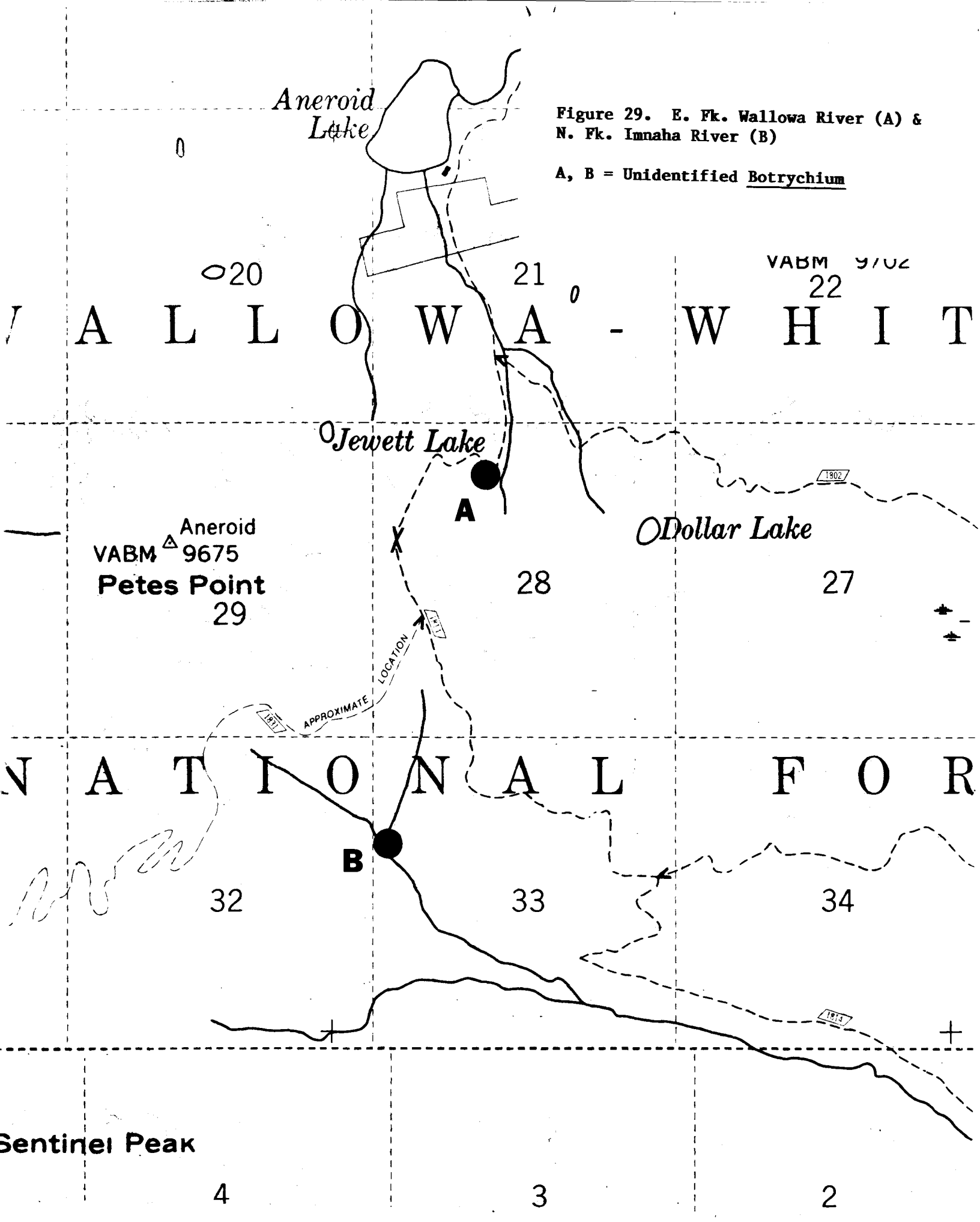


Figure 29. E. Fk. Wallowa River (A) & N. Fk. Imnaha River (B)

A, B = Unidentified Botrychium

Fig 29

A 3 B

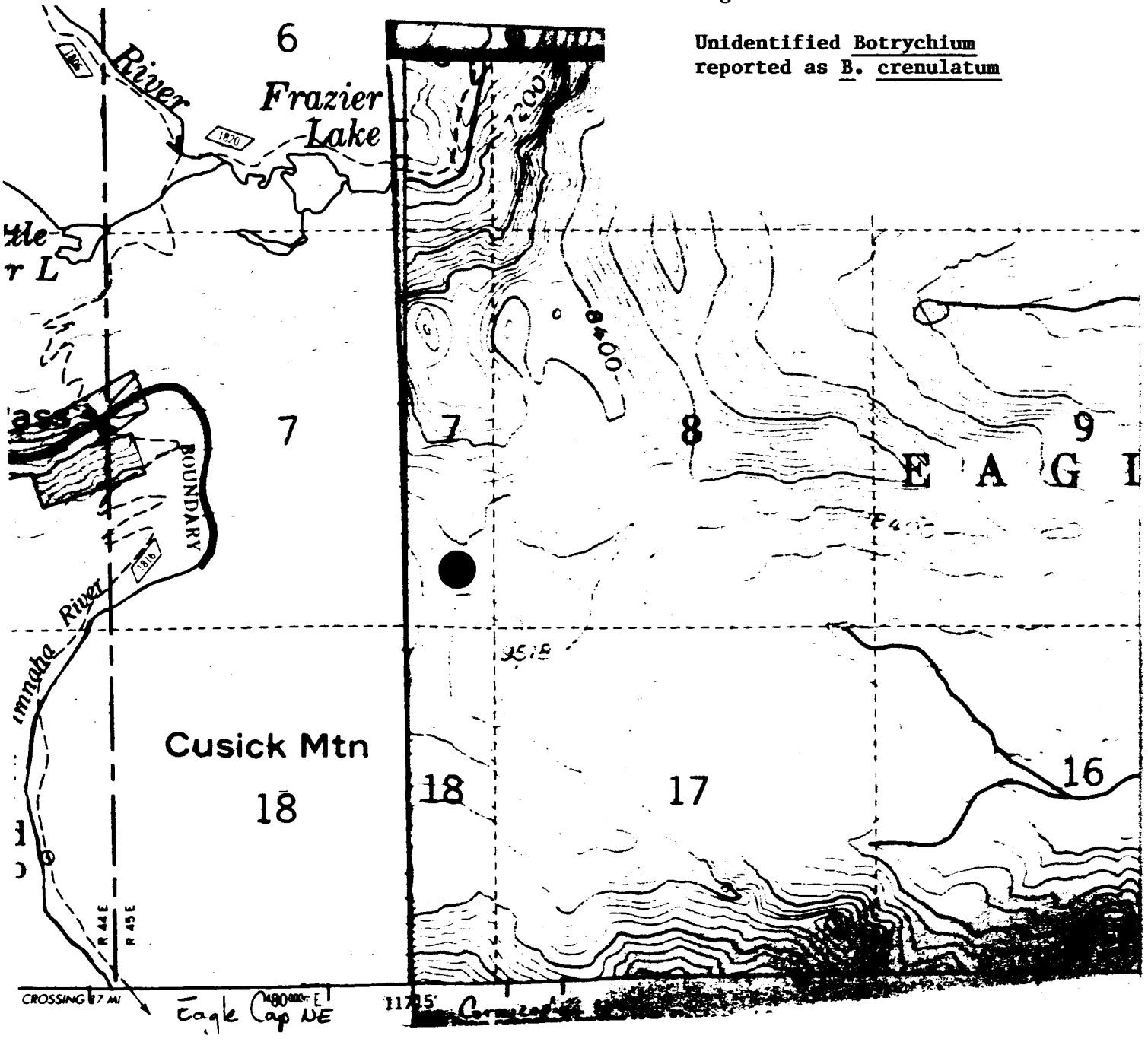
Botr. sp.

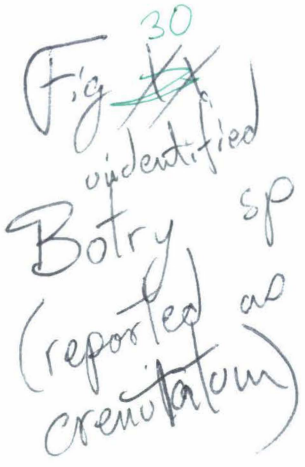
prob. winogroensk

B=33

Figure 30. W. Fk. Wallowa River

Unidentified Botrychium
reported as B. crenulatum




30
Fig
unidentified
Botry sp
(reported as
crenulatum)